NASA TECHNICAL MEMORANDUM

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STUDY OF AIRBORNE SCIENCE EXPERIMENT MANAGEMENT CONCEPTS FOR APPLICATION TO SPACE SHUTTLE

VOL III – APPENDIXES

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INTRODUCTION

The Airborne Science/Shuttle Experiments System Simulation (ASSESS) program was started in response to strong interest in the management of airborne research by the Airborne Science Office (ASO) at Ames Research Center, and in the similarities between the Airborne Science operation and that planned for carrying experimenters aloft on a regular schedule to conduct space research in the Shuttle Sortie Lab. The ASSESS program was instituted with the objective of conducting exhaustive studies of the established airborne science concept as it may apply to Shuttle planning. The program is in two phases: Phase A involves detailed observations and study of ongoing missions managed by the Airborne Science Office, with the objective of translating this experience into the Sortie Lab program; and Phase B involves studies of airborne missions constrained to represent Sortie-mode missions with the purpose of providing additional information for Shuttle planning.

This is the first in a series of reports covering the Phase A observations. It encompasses observations for the period April to November 1972 for the Lear Jet and CV-990 aircraft. The report has been written in three separate volumes: Volume I is an executive summary which provides a quick overview of the findings of the study (ref. 1); Volume II contains the main body of information and discussion (ref. 2); and this third volume consists of a set of appendixes which give detailed information specific to the airborne missions studied. Appendixes A through D cover four CV-990 missions; three were based at locations remote from Ames and, thus, are identified as expeditions. The AIDJEX and Meteor Shower Expeditions were based in Alaska while the Ocean Color Expedition based on the east coast of the United States, at Las Palmas in the Canary Islands, and at Dakar, Senegal in western Africa. The fourth—the August 1972 mission—was locally based. Observations on a fifth CV-990 mission during this time period were interrupted by other commitments and have not been reported herein, although some of the preliminary results on experiment development and equipment definition have been presented in Volume II of this report for the November 1972 mission.

Lear Jet missions (or flight series) during this time were 17 in number, involving experimental teams from 7 different organizations (one university department fielded two separate research teams). These are grouped together in appendix E, herein, since the procedures for all Lear Jet missions are quite similar. On the other hand, in Volume II each of the 17 Lear Jet missions was considered a separate research effort, even when a research team returned for successive flight series, because team membership changed, research objectives varied, and equipment was upgraded as a result of previous flight experiences.

Most of the data for this report were gathered under contract by a team of observers from Northrop Services, Inc. The team included Bernard Shyffer, John F. Reeves, Gaylord M. Androes, and Norman J. Donnelly. Their contributions have been of great assistance to the ASSESS program.

References

1. TM X-62,288 Study of Airborne Science Experiment Management Concepts for Application to Space Shuttle, Vol. I, July 1973.
2. TM X-62,287 Study of Airborne Science Experiment Management Concepts for Application to Space Shuttle, Vol. II, July 1973.

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Appendix A

AIDJEX EXPEDITION

The AIDJEX (Arctic Ice Dynamics Joint Experiment) Expedition was the second part of a dual-purpose mission involving (1) a series of eight flights over the continental United States to provide definition and design data on experiments for the proposed Earth Observation Satellite (EOS); and (2) a series of seven flights over a test site in Alaska to study the interactions between the motions of the atmosphere, the pack ice, and the liquid ocean. The first flight series did not fall within the ASSESS study period and therefore is not evaluated here. It did involve the same instrumentation and personnel as the AIDJEX flight series, however, and hence the experiments flown in the AIDJEX series had been designed and constructed, and were fully operational prior to the ASSESS evaluation period.* As this was the first mission covered in the ASSESS study, the observations were not as broad or detailed as those developed in subsequent missions; additional observational data are being evaluated from the Bering Sea Experiment (BESEX) mission in February-March 1973, which included essentially the same experiments as those on the AIDJEX flights.

Mission Objectives and Operating Procedures

Mission Origin

Both the EOS-related and AIDJEX flight series were developed under the auspices of a NASA research center, whose management assigned the project scientist, approved the selection of primary experiments and the overall mission plan, and supplied a coordinator to assist in the installation of equipment at Ames.

Mission Objectives and Test Site

AIDJEX is an ongoing international program to provide data on the interactions between the motions of the atmosphere, the pack ice, and the liquid ocean as a basis for improving the prediction of weather conditions for North America. For the period of CV-990 participation, the ground test site consisted of an array of three manned and five unmanned stations (data buoys) centered 450 to 550 Km north of Point Barrow, Alaska. The airborne instruments obtained microwave, infrared, and photographic imagery of the test-site area, while AIDJEX scientists based on the ice provided ground-truth data. Specific experiments are listed in table A-1.

ASSESS observations of the mission began with the ferry flight to Alaska on April 3, 1972. Seven overflights of the test site were made from Fairbanks International Airport and Eielson AF Base before the return flight to Moffett Field on April 24, 1972.

*One exception was the solar photometry experiment which joined the AIDJEX Expedition for two flights.

TABLE A-1. EXPERIMENTS FLOWN ON THE AIDJEX EXPEDITION

INSTRUMENTATION	EXPERIMENTER'S AFFILIATION	MEASUREMENT
1. 19.35-GHz (1.55-cm) IMAGING MICROWAVE RADIOMETER; BEAM WIDTH (BW) = 2.85° (±50° NADIR SCANNING).	NASA SPONSORING CENTER	BRIGHTNESS TEMPERATURE FROM SEAS, SEA ICE, CLOUDS, DETERMINATION OF SNOW AND SOIL MOISTURE
2. 1.42-GHz (21-cm) MICROWAVE RADIOMETER, DUAL POLARIZED; BW = 15° (NADIR VIEWING).		BRIGHTNESS TEMPERATURE FROM SEAS, SEA ICE, CLOUDS, DETERMINATION OF SNOW AND SOIL MOISTURE.
3. 4.99-GHz (6-cm) MICROWAVE RADIOMETER, DUAL POLARIZED; BW = 8° ALONG FLIGHT PATH (38° AFT NADIR VIEWING).		BRIGHTNESS TEMPERATURE FROM SEAS, SEA ICE, CLOUDS, DETERMINATION OF SEA SURFACE TEMPERATURE.
4. 37-GHz (0.81-cm) MICROWAVE RADIOMETER, DUAL POLARIZED; BW = 5° (38° AFT NADIR VIEWING).		BRIGHTNESS TEMPERATURE FROM SEAS, LAKE AND SEA ICE, AND CLOUDS.
5. LASER GEODOLITE (NADIR VIEWING).		SEA ICE ROUGHNESS AND OCEAN WAVE SPECTRA.
6. 10.69-GHz (2.8-cm) MICROWAVE RADIOMETER. DUAL POLARIZED; BW = 6.5° (38° AFT NADIR VIEWING).	NASA	BRIGHTNESS TEMPERATURE FROM SEAS, LAKE AND SEA ICE, AND CLOUDS.
7. NIMBUS E, FIVE-CHANNEL MICROWAVE SPECTROMETER; BW = 10° (NADIR VIEWING).	NASA	MICROWAVE RADIANCES: 22.235 GHz (1.35 cm) WATER VAPOR 31.4 GHz (0.8 cm) WATER VAPOR 53.65 GHz (0.56 cm) LOW TROPOSPHERIC SOUNDING 54.9 GHz (0.546 cm) UPPER TROPOSPHERIC SOUNDING 58.8 GHz (0.51 cm) LOW STRATOSPHERIC SOUNDING
8. & 9. 9.3-GHz (3.2-cm) AND 31.4-GHz (0.96-cm) MICROWAVE RADIOMETERS; BW = 17° AND 10°, RESPECTIVELY (ZENITH VIEWING).	NASA	SKY RADIANCES UNDER VARIOUS WEATHER CONDITIONS.
10. RS-310 INFRARED IMAGER (±45° NADIR SCANNING).	OTHER GOVERNMENT AGENCY	INFRARED SURFACE RADIANCE MEASUREMENT; SURFACE TEMPERATURE MAPS. WAVELENGTH REGION: 7.54 to 10.0 μm.
11. TWO SINGLE CHANNELS AND ONE MULTICHANNEL INFRARED RADIOMETERS (ZENITH, HORIZONTAL, AND NADIR VIEWING).	OTHER GOVERNMENT AGENCY	INFRARED RADIANCES FROM THE ATMOSPHERE AND EARTH SURFACE UNDER VARIOUS WEATHER CONDITIONS: ZENITH VIEWING, 17 TO 30 μm, WATER VAPOR HORIZONTAL VIEWING, 15.0 TO 15.2 μm, STATIC AIR TEMPERATURE NADIR VIEWING, 9.5 TO 11.5 μm, SURFACE TEMPERATURE.
12. ALUMINUM OXIDE HYGROMETER.	NASA SPONSORING CENTER	ATMOSPHERIC WATER VAPOR (DEW POINT/FROST POINT MEASUREMENTS).
13. SOLAR PHOTOMETER.	STATE UNIVERSITY	SOLAR BRIGHTNESS.

General Operating Procedures

Much of the mission activity was concerned with assembling weather data. A number of events typically occurred before and during each flight. Late each afternoon, the Airborne Science Office (ASO) mission manager, the project scientist, and the liaison scientist gathered at the weather station to examine the prognosis for the following day. Additional weather information from the ESSA satellite was obtained from the NASA tracking station at Gilmore Creek, near Fairbanks. Radio-propagation conditions permitting, checks were made by phone via Point Barrow to the ice stations for the latest local weather information. An evaluation of the probable weather conditions for the following day provided the basis for manning the next flight.

Inflight changes of the original flight plan were often made in response to local conditions on the ice. Such changes were made after discussion among the mission manager, the project scientist, the liaison scientist, the navigator, and the pilots. In some cases, desired flight-plan changes were inhibited by air traffic control.

Details of mission operations and the roles of the principal participants and support personnel are given in the next section.

Mission Management and Personnel

ASO Program/Mission Manager

Detailed mission planning and integration of the individual mission experiments were accomplished by the Ames ASO program manager in consultation with the project scientist appointed by the sponsoring NASA center. As with all major CV-990 missions, the ASO program manager also served as mission manager on all flights in the AIDJEX series. As noted, he participated in decisions on flight scheduling and changes of flight plans in response to contingencies or research opportunities developing en route.

During the flight, the mission manager normally operated from a position at the experiment control panel in the front of the aircraft where he could monitor and respond to intercom discussions among the individual experimenters. At the next control panel position, the mission manager or his assistant recorded time and position coordinates at the beginning and end of each data run, from the data produced by the time-code generator and the aircraft's inertial navigation system. Typically, the operation of experiment and support equipment was checked and coordinated. In particular, the various components of the ASO-furnished data systems were checked to ensure optimum performance in terms of specific experimental requirements—that is, proper photographic coverage, suitable rates of printout from the Airborne Digital Data Acquisition System (ADDAS) and the proper selection of data to be recorded.

Project Scientist

The project scientist had overall responsibility for the performance of the primary AIDJEX experiments. During the flights, he observed ice conditions and called attention to features that

should be recorded on the various instruments. Between flights, he participated directly in the buildup of photomosaics from the scanning radiometer, false-color pictures.

Liaision Scientist

The sponsoring NASA center arranged for a liaison scientist from the U.S. Geological Survey to coordinate flight observations with ground-based AIDJEX scientists. The liaison scientist participated in the first six of the seven over-ice data flights, often reporting ice conditions for the benefit of the experimenters from his position in the cockpit. He also obtained the latest position coordinates in radio communications with ice stations in proximity to the aircraft. He participated in weather briefings and decisions on subsequent flight scheduling.

Aircraft Facilities Manager

The ASO aircraft facilities manager was responsible for assignment of electrical power to the various experiments on a noninterfering basis, and the maintenance of the ADDAS and other experiment support facilities.

Data Systems Manager

The data systems manager operated the onboard computer system (ADDAS), made any necessary adjustments to the programs handling experimental data, and prepared copies of data records as requested by individual experimenters.

Data Typists

Comments by experimenters, times of data runs, and other information of interest were entered by the data typist into the ADDAS record for later printout and correlation with relevant aircraft and experiment parameters.

Inflight Technicians

Two aircraft technicians accompanied all flights. An electronics technician had the responsibility for the aircraft timing system, operation of the intercom, and the closed-circuit TV equipment. He was available during the flights to assist experimenters. An aircraft mechanic was responsible for the operation of special windows and provided other assistance as needed in support of aircraft systems and experimenters' equipment.

The Role of The Experimenter

The experimental equipment used in the AIDJEX Expedition had been installed and checked out prior to the ASSESS study phase. Therefore, the activities of the experimenters in the design and construction of their equipment were not observed. Experiment operation and specific instances of data reduction were observed however. Examples are given below.

Experiment Operation

The roles of the experimenters varied widely, depending on the nature of the experiment. Some experiments were operated during flight by technicians; others were operated by scientists. Both types of personnel operated their experiments successfully during the AIDJEX flight series. However, the technicians did not provide any inflight interpretation of data; thus, any potential value of this information to other experimenters during a flight was lost (for example, data from the 1.42-, 4.99-, and 19.35-GHz scanning radiometers, the first three listed in table A-1).

A different type of situation existed with the NIMBUS radiometers (experiment 7, table A-1). Initially, this experiment was operated by a technician; part way through the mission, the technician was replaced by a scientist who had been involved in the instrument's development. The scientist was now able to make real-time interpretations of the data, but he was unfamiliar with the actual operation of the equipment and occasionally had difficulty selecting the proper switch setting, which were poorly identified on the switch panels. (Some details on a similar problem with the 31.4 GHz radiometer, operated by the same team of experimenters, are given on p. A-10).

The 37-GHz dual-polarized radiometer, on the other hand, was operated by a scientist who interpreted the readout when points of interest were noted. In particular, he could detect the presence of open water with this instrument, even though the open lead was too narrow to be seen with the naked eye. This scientist performed well despite the fact that he had not been involved in the instrument's development and his professional background was not in that field.

The RS-310 infrared imager was operated by the principal investigator—a scientist thoroughly familiar with the operation of the instrument, and able to obtain immediate data on the estimated temperature of interesting phenomena beneath the aircraft. Despite an inherent limitation in instrument range controls, he devised a method of operation that assured optimum performance of his equipment.

In addition to their inflight responsibilities, three of the men aboard the CV-990 were invited to give seminars on their experiments at the Geophysical Institute, University of Alaska. These seminars were attended by members of the Institute staff, the scientific experimenters from the aircraft, and the mission manager.

Data Reduction

Two examples of data reduction were studied during the mission. These involved the handling of data from the 19.35-GHz imaging (scanning) radiometer and the RS-310 infrared imager. The

scanning radiometer was a prime experiment, and special arrangements had been made for its complex data processing. An inflight strip printer was intended to produce a mosaic, but owing to poor gray-scale resolution its function was limited to merely indicating proper instrument operation.

Special data-processing equipment for making false-color mosaics of the scanning radiometer data was installed in a hotel room in Fairbanks. This equipment consisted of two racks of electronic equipment including a tape handler, computer, and color TV monitor. (The magnetic tape from each day's run first was duplicated at the NASA tracking station at Gilmore Creek.) Processing was handled by a technician provided by the equipment manufacturer and consisted of dividing the data into individual frames covering about a minute of forward motion, numbering these frames, and finally developing a presentation in color. The colors corresponded to a predetermined scale of apparent temperature as measured by the radiometer. Each frame was photographed as it was presented so that a mosaic of the data could be made.

The first set of these prints was made with a large camera and Polaroid film; subsequent data were photographed on 35mm film and the mosaics made from prints. Film processing services were provided by the Geophysical Institute at the University of Alaska. Several such mosaics were made that showed the equipment was operating properly and that it was possible to detect small differences in apparent temperature as, for example, between first-year ice and multiyear ice.

The Geophysical Institute also processed film from the RS-310 infrared imager, and a photomosaic was made from the data to match those from the 19.35-GHz microwave scanner. A comparison of the two presentations showed that temperature differences were magnified by the false color of the microwave scanner presentation, although the resolution was rather coarse, while the photomosaic from the IR imager presented a high degree of resolution that exceeded the specifications of the instrument. From an altitude of 30,000 feet, for example, 10-foot wide pressure ridges were easily recorded by the IR imager.

Design and Construction of Experiment Hardware

Characteristics of the experiments flown on the AIDJEX flight series are given in table A-2 by components and type of construction or source (e.g., off-the-shelf). The experiments are designated by the same numbers as in table A-1. Most of the radiometers were custom-commercial units, with off-the-shelf indicators and recorders added to complete the experimental packages.

The NASA radiometers (items 1 through 4) were all custom built by the same company. The 19.35-GHz scanner was the prototype model of a device developed for the NIMBUS satellite. Off-the-shelf recorders and instruments were used for "quick-look" and data recording; for example, a commercial photoprinter provided a real-time, low-gray-scale-resolution printout.

The five-channel NIMBUS spectrometer (7) was designed by members of a university staff and custom constructed by a commercial firm. Off-the-shelf recorders and oscilloscopes were incorporated for quick-look capability and data recording.

TABLE A 2. EXPERIMENT CHARACTERISTICS

EXPERIMENT	COMPONENT	CONSTRUCTION TYPE/SOURCE			
		OFF THE SHELF	CUSTOM COMMERCIAL	MODIFIED COMMERCIAL	EXPERIMENTER BUILT
1. 19.35-GHz IMAGING MICROWAVE RADIOMETER (MAPS BRIGHTNESS TEMPERATURE FROM SEAS, ICE, AND CLOUDS)	ELECTRONIC SCANNED ARRAY ANTENNA		X		
	RADIOMETER		X		
	PHOTOGRAPHIC RECORDER	X			
2. 1.42-GHz MICROWAVE RADIOMETER (MEASURES BRIGHTNESS TEMPERATURE FROM SEAS, ICE, AND CLOUDS)	ANTENNA		X		
	RADIOMETER		X		
	RECORDER, STRIP CHART	X			
3. 4.99-GHz MICROWAVE RADIOMETER (MEASURES BRIGHTNESS TEMPERATURE FROM SEAS, ICE, CLOUDS; SEA SURFACE TEMPERATURE)	ANTENNA		X		
	RADIOMETER		X		
	RECORDER, STRIP CHART	X			
4. 37-GHz MICROWAVE RADIOMETER (MEASURES BRIGHTNESS TEMPERATURE FROM SEAS, LAKES, CLOUDS, ICE)	ANTENNA		X		
	RADIOMETER		X		
	RECORDER, STRIP CHART	X			
5. LASER GEODOLITE (MEASURES SEA ICE ROUGHNESS CHARACTERISTICS AND OCEAN WAVE SPECTRA)	POWER SUPPLY	X			
	LASER	X			
	OPTICS		X		
	PULSING CIRCUITRY	X			
	DETECTOR CIRCUIT		X		
	TIMING CIRCUITRY	X			
	STRIP CHART RECORDER	X			
	STRIP CHART RECORDER (LIQUID DEVELOPER)	X			
6. 10.69-GHz MICROWAVE RADIOMETER (MEASURES BRIGHTNESS TEMPERATURE FROM SEAS, LAKES, CLOUDS)	ANTENNA		X		
	RADIOMETER		X		
	RECORDER, STRIP CHART	X			
7. NIMBUS E FIVE-CHANNEL MICROWAVE SPECTROMETER (MEASURES MICROWAVE RADIANCES OF WATER VAPOR AND OXYGEN IN THE ATMOSPHERE)	ANTENNAS (5)		X		
	H_2O RADIOMETERS				
	22.2 GHz			X	
	31.4 GHz			X	
	O_2 RADIOMETERS				
	53.6 GHz			X	
	54.9 GHz			X	

TABLE A 2 EXPERIMENT CHARACTERISTICS (CONCLUDED)

EXPERIMENT	COMPONENT	CONSTRUCTION TYPE/SOURCE			
		OFF-THE-SHELF	CUSTOM COMMERCIAL	MODIFIED-COMMERCIAL	EXPERIMENTER BUILT
7. CONTINUED	58.8 GHz			X	
	POWER SUPPLY	X			
	CONTROL PANELS (2)				X
	ANALOG PANEL				X
	TEMPERATURE MONITOR	X			
	STRIP CHART RECORDER	X			
	A/C INTERFACE DRAWER				X
	MULTIPLEXER		X		
	DATA PROGRAMMER		X		
	S/C SIMULATOR		X		
	MAGNETIC TAPE RECORDER (2)	X			
	TEMPERATURE CONTROLLER				X
	HOT LOAD OVEN CONTROLLER				X
	PAPER TAPE PUNCH	X			
8. & 9. 9.3 AND 31.4 GHz MICROWAVE RADIOMETERS (MEASURE SKY RADIANCE UNDER VARIOUS WEATHER CONDITIONS)	ANTENNA (2)		X		
	READIOMETER (2)		X		
	RECORDER (2), STRIP CHART	X			
10. RS-310 INFRARED IMAGER (MEASURES IR RADIANCE FROM EARTH)	DETECTOR HOUSING	X			
	CONTROL PANEL	X			
	MONITOR OSCILLOSCOPE	X			
	THERMOMETER	X			
	POWER SUPPLY	X			
	HEATER CONTROL PANEL		X		
	TAPE RECORDER	X			
11. TWO SINGLE-CHANNEL AND ONE MULTI-CHANNEL IR RADIOMETERS (MEASURE IR RADIANCES FROM ATMOSPHERE AND EARTH SURFACE)	DIGITAL VOLTMETER	X			
	CONTROL PANEL				X
	THERMOMETERS (3)	X			
	SENSOR UNIT (3)	X			
12. ALUMINUM OXIDE HYGROMETER (MEASURES ATMOSPHERIC WATER VAPOR PARAMETERS)	AIR SCOOPS (2)				X
	HYGROMETER SENSORS (2)	X			
	CONTROLLER	X			
	HYGROMETER ELECTRONICS		X		
	STRIP CHART RECORDER	X			
	DATA OUTPUT PANEL				X
13. SOLAR PHOTO METER	DETECTOR			X	
	POWER SUPPLY			X	

The RS-310 infrared imager (10) is a commercial version of a military reconnaissance device with an oscilloscope added for real-time examination of the signal.

Interface Requirements

Experiments flown on the AIDJEX flight series had already been installed and flown for the EOS flight series before the ASSESS observation period began. Thus, no observational data are available on the handling of experiment/aircraft interface requirements.

Figure A-1 shows the cabin floor plan of the CV-990, essentially as it was for the AIDJEX Expedition. Instrument sensors were mostly mounted in nadir and zenith windows; little use was made of the regular passenger and 65°-elevation windows. The bulk of the electronic equipment for this mission was mounted internally in standard racks. Power demands for this equipment were modest and posed no special problems.

The experimenters made extensive use of the aircraft intercom systems. Points of interest were often called out over the intercom by an observer in the cockpit, and then reported on by others as the particular phenomenon showed or failed to show on a given instrument. The intercom was also used for safety checks by personnel moving into the cargo compartments to change film or reload cryogenics.

Communications with ice stations were also important. Direct contact was desirable for mission coordination and a necessary condition prior to low-level passes over the stations. On one flight, auroral blackout prevented direct HF (high frequency radio) communications with the ice stations, and low-level passes were not made.

Experiment Testing and Reliability

The only opportunity to observe AIDJEX experiment testing was after arrival at Eielsen AFB, Alaska. Part of a day there was used in recalibration of downward-looking microwave radiometers, principally the 19.35-GHz scanner. A large bath of liquid nitrogen was used to provide a reference temperature source at 77°K, which was checked against the existing instrument calibration. The instruments were found to be still in calibration, and no adjustments were needed.

A recheck of calibration was also made on the RS-310 infrared imager using a bucket of slush at 0°C as the reference temperature source. Again, no need for readjustment was found.

In general, equipment operated reliably and performed as expected. Much of the equipment and many of the experimenters had flown before, of course, which contributed to the high overall success of the mission. The relatively few failures observed make meaningful comparisons of commercial and custom equipment difficult. Examples of equipment failures and operational problems are given below.

Sample Problem History: 31.4-GHz Zenith Radiometer

The 31.4-GHz zenith radiometer was inoperative for about two hours on one flight because of a defective switch internal to the equipment housing. Repairs were made during the flight by the experiment operator with the aid of the aircraft mechanic. On another flight, some data were not recorded because of an improper switch position on the control panel, which was not discovered until the postflight check. On the last data flight, the data-collection system for this experiment failed. A broken lead was located on one electronic board, but repair did not correct the problem. Data were not lost during either of the last two incidents because the signals were also fed directly to the ADDAS.

Control panels on this custom-made equipment (as for the NIMBUS radiometers) were inadequately labeled as to both equipment designation and switch function. In addition, the change of experiment operator noted in an earlier section undoubtedly contributed to the recording error cited above. (Note that both the 31.4-GHz and the NIMBUS radiometer experiments were installed and operated by the same team of experimenters.)

Electrical Interference

Communications from the aircraft caused minor interference on at least three radiometer channels. Sensitivity to communications frequencies was positively identified for the 4.99- and 10.69-GHz instruments, as well as the IR imager.

In the case of the IR imager, the aircraft distance measuring equipment (DME) antenna produced interference on the oscilloscope display of the experimenter's control panel. Fortunately, because of the time constants in the imaging system, this interference was not picked up on the recorded images.

Minor interference showed up on the strip chart recorder of the 1.42 GHz radiometer. The interference was traced to the 60-Hz heaters on the NIMBUS spectrometer. The two experiments were located some distance apart and on opposite sides of the aircraft. Ground-loop coupling was suspected as the cause.

Support Utilities Performance

In general, the ADDAS system operated well. However, the line printer had frequent minor problems during the mission, and although repairs were readily accomplished, continual monitoring was required to assure operation. The video recorder, which is one of the ASO utility systems, sometimes ran out of tape at inconvenient times, causing loss of a few minutes of TV display and intercom record. The time capacity of the recorder is about 1-1/2 hours, but since no research data were lost during the tape-change interval, the information gaps are of minor importance.

No serious problems were observed with the operation of the aircraft inertial navigation system (INS). Some minor inconvenience resulted from the slow update of the INS outputs of distance-to-go and time-to-go at the flight director's station; the slow changes in these parameters

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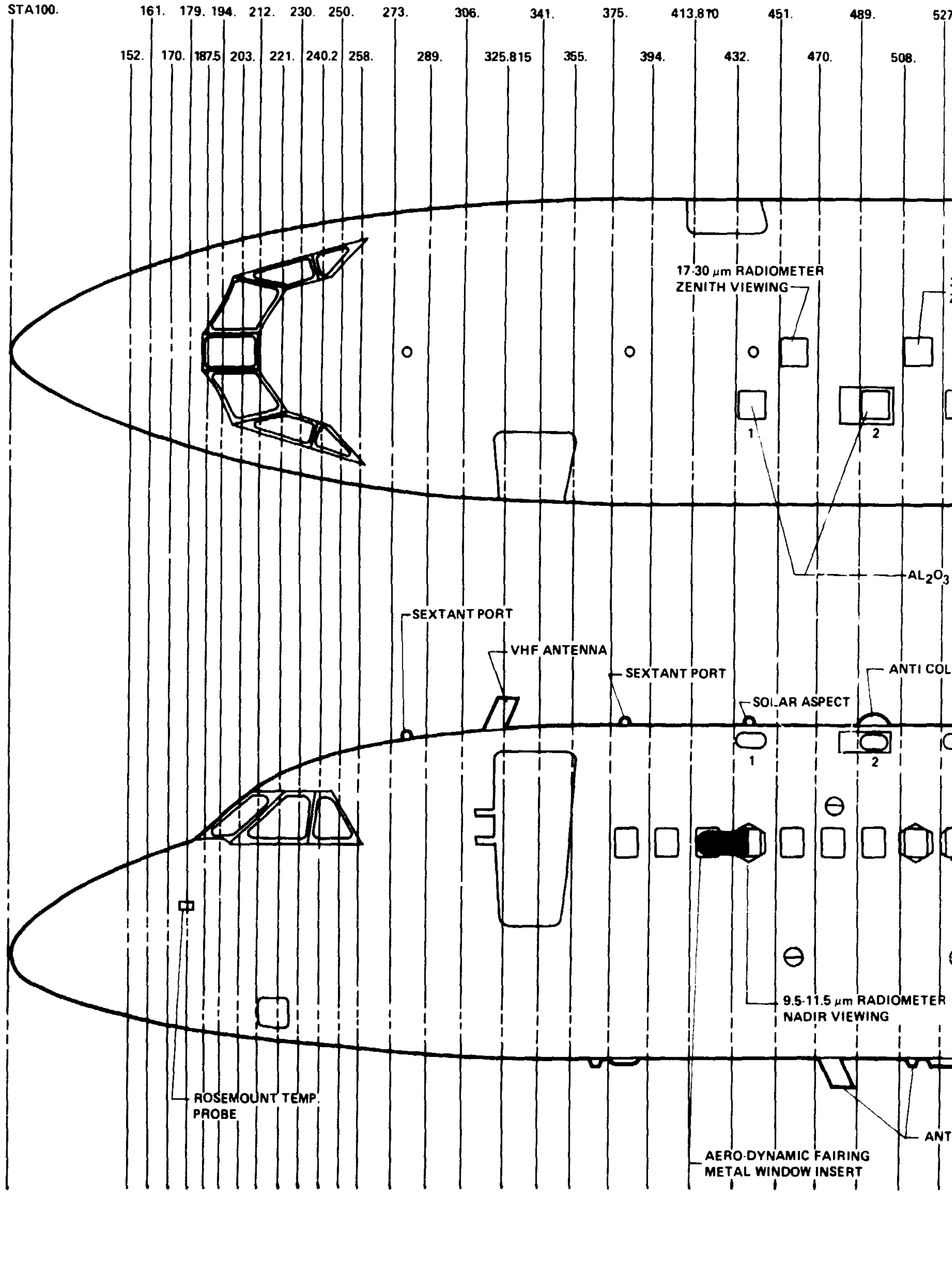

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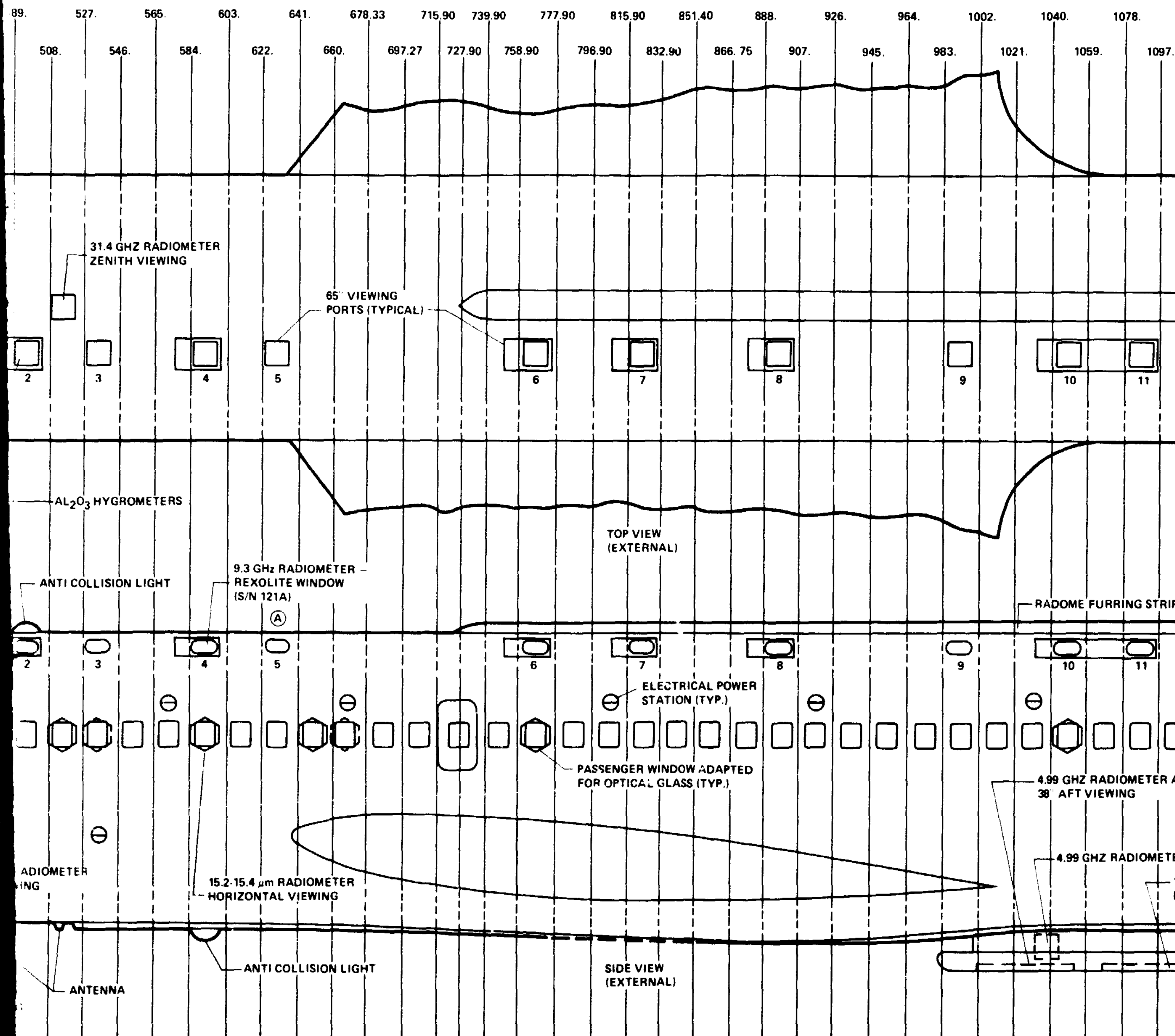

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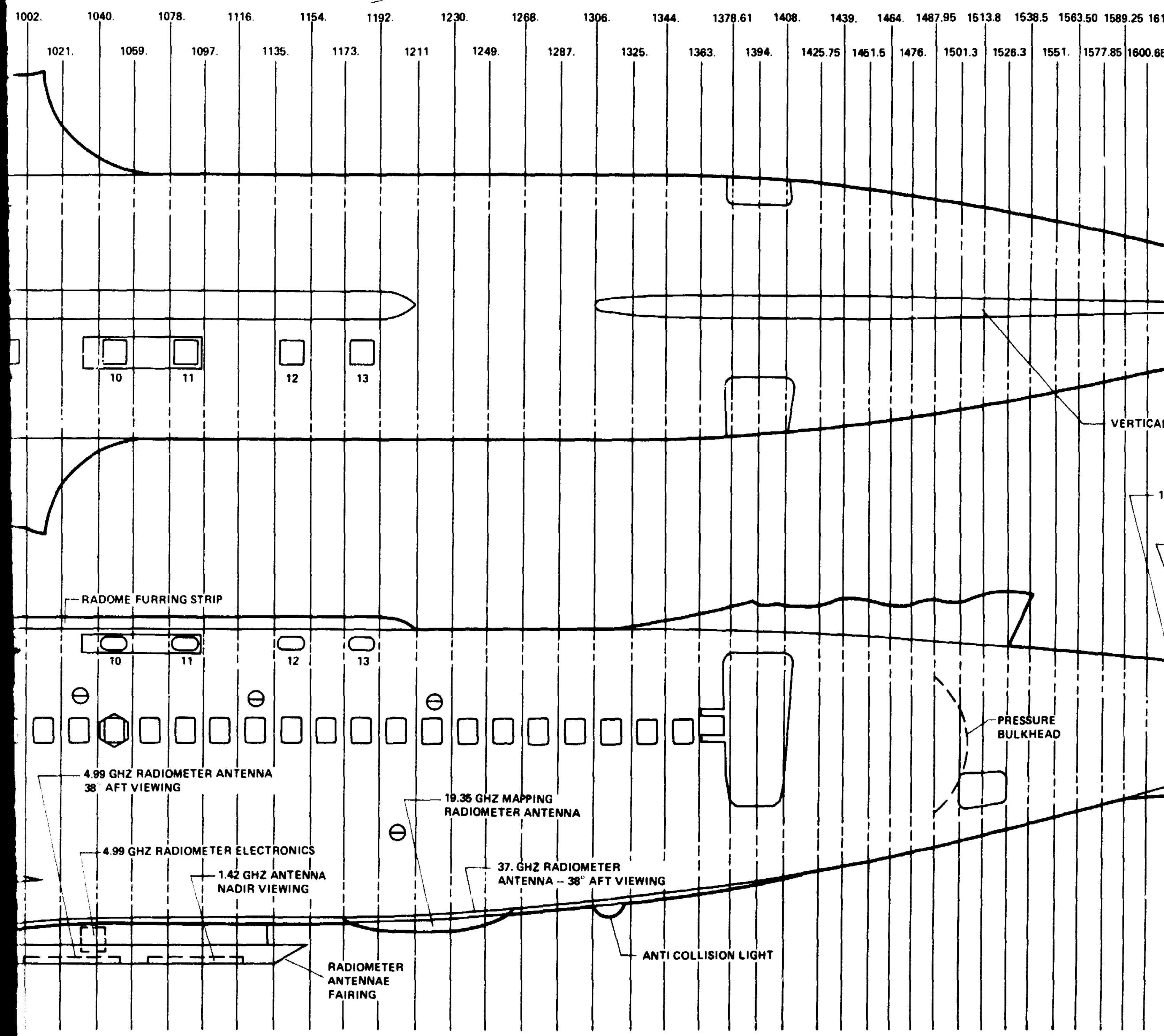

Figure A-1 – Layout of experiments in CV–990

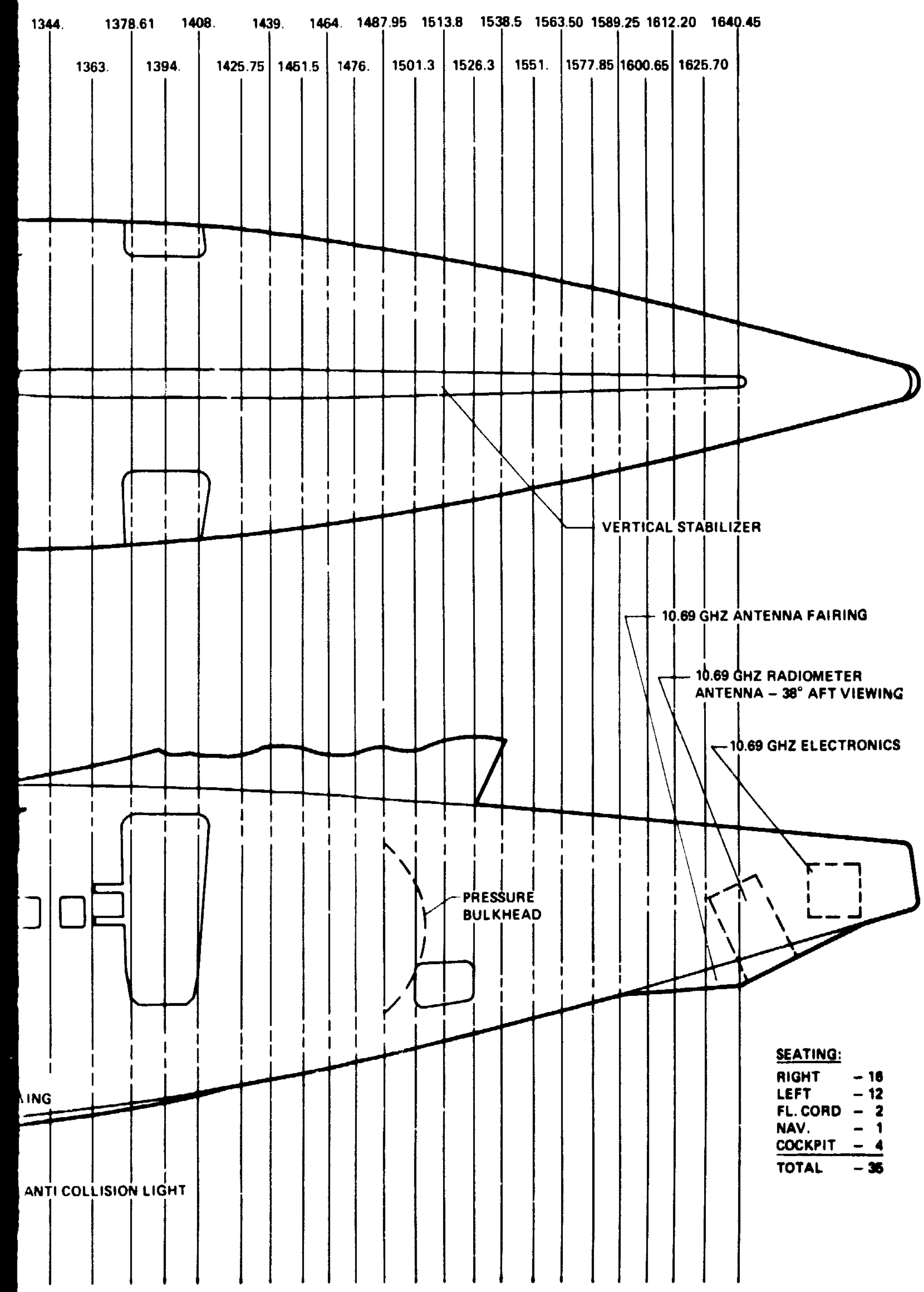

Figure A-1 – Layout of experiments in CV–990 aircraft.

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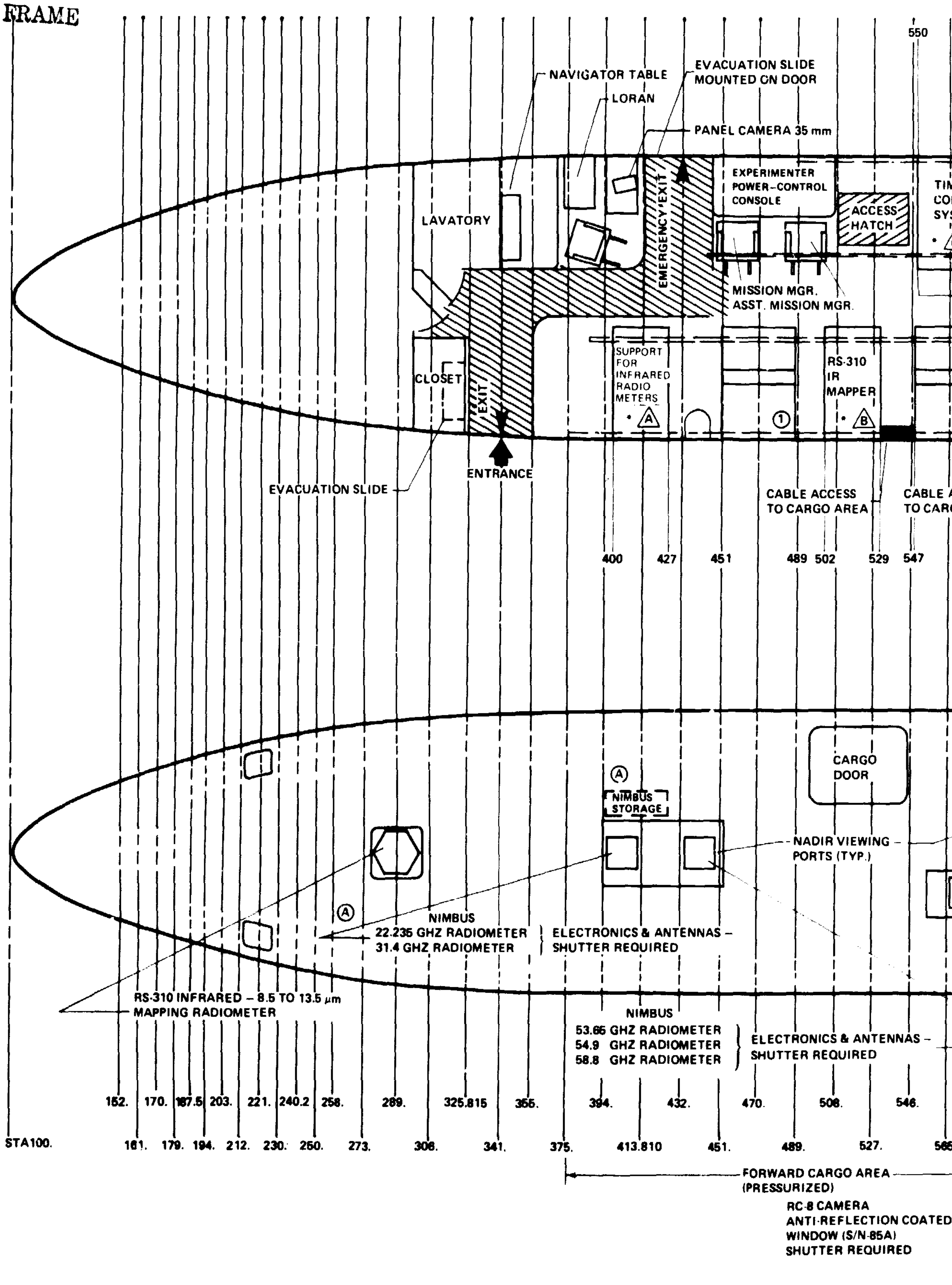

Figure A-1 – Layout of experiments in CV–990 aircraft - concluded.

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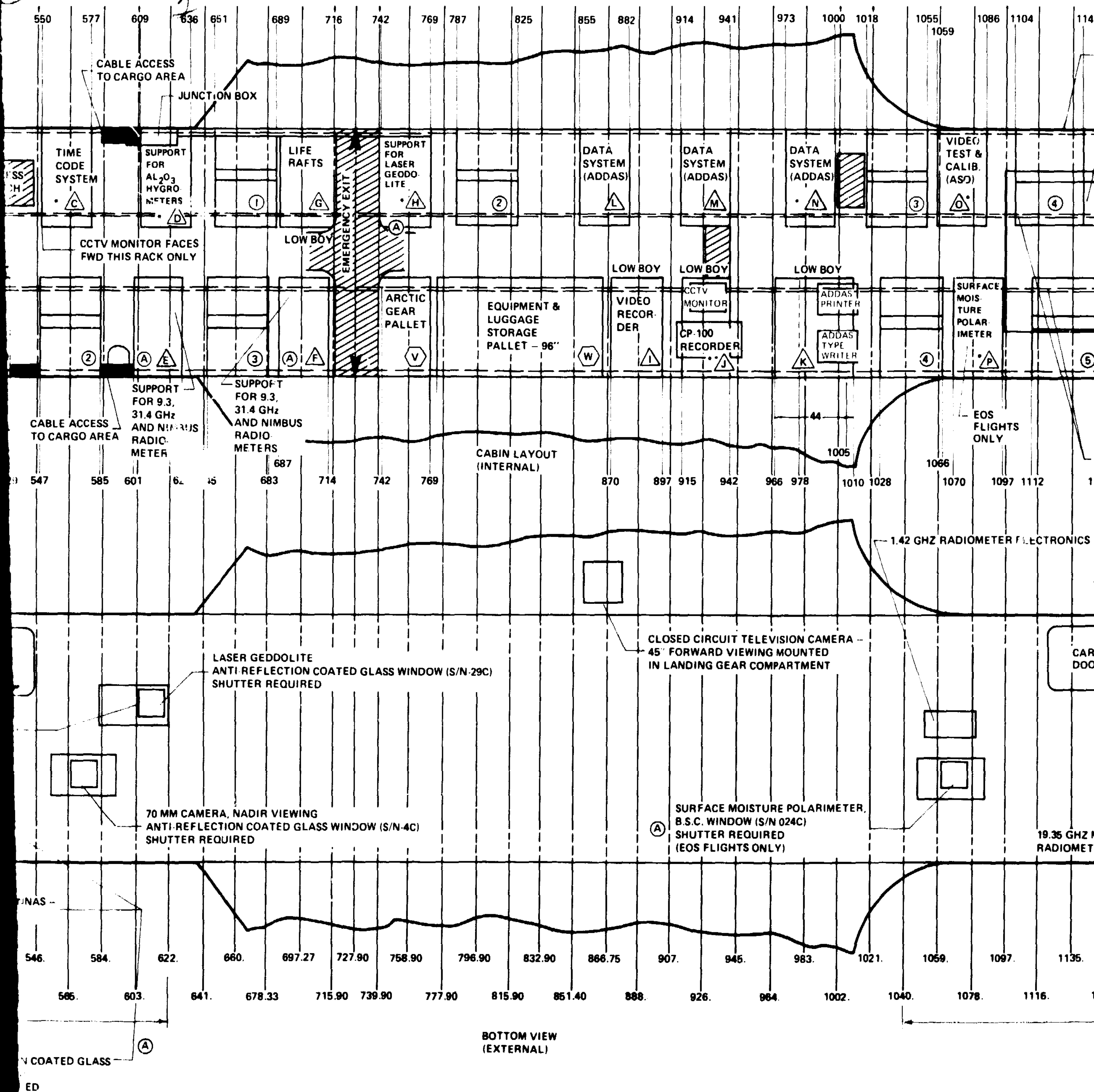
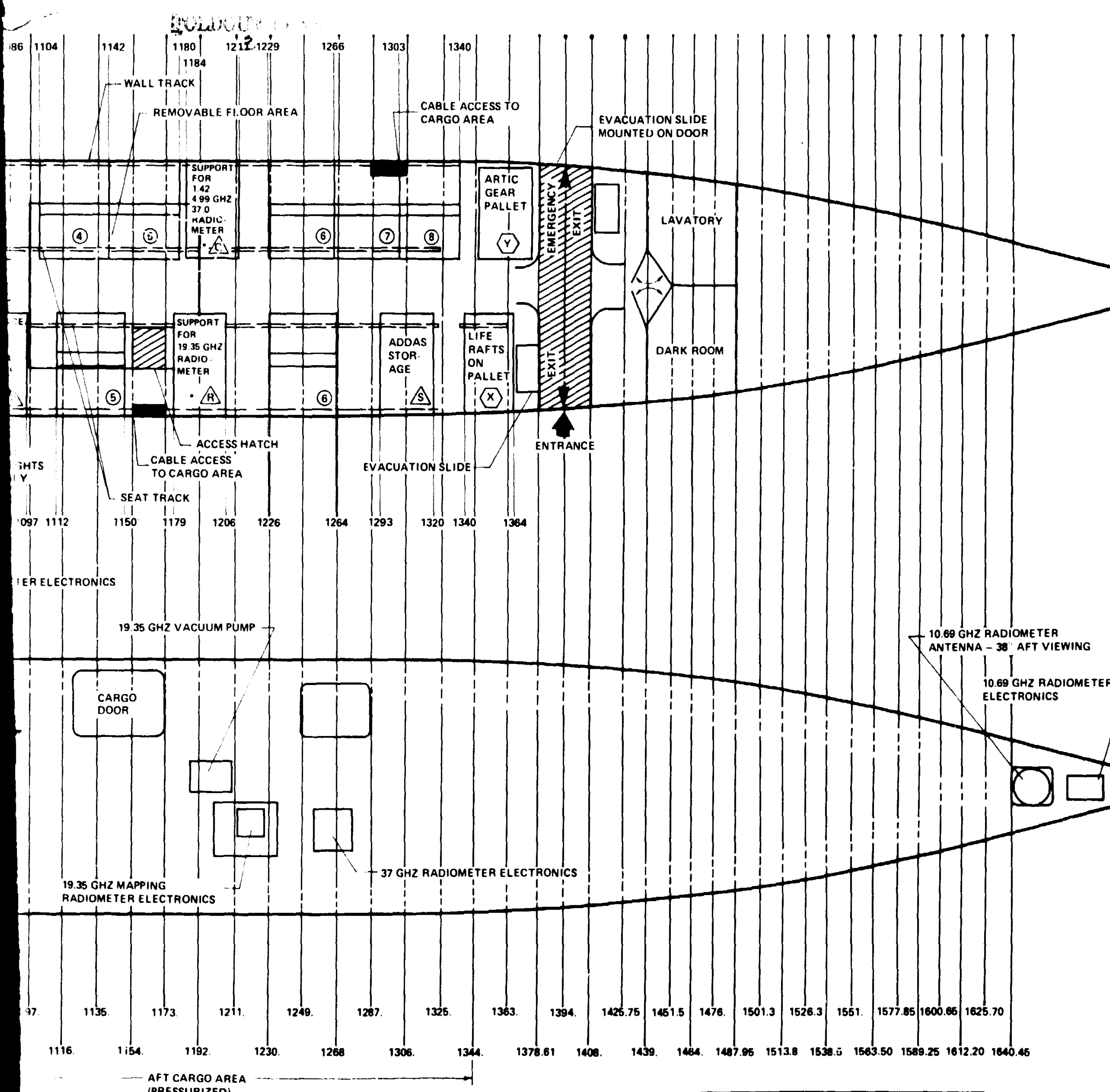




NOTES:

ORIGINAL LAYOUT DATED 12/6/71

(A) - LAYOUT REVISED 2/17/72

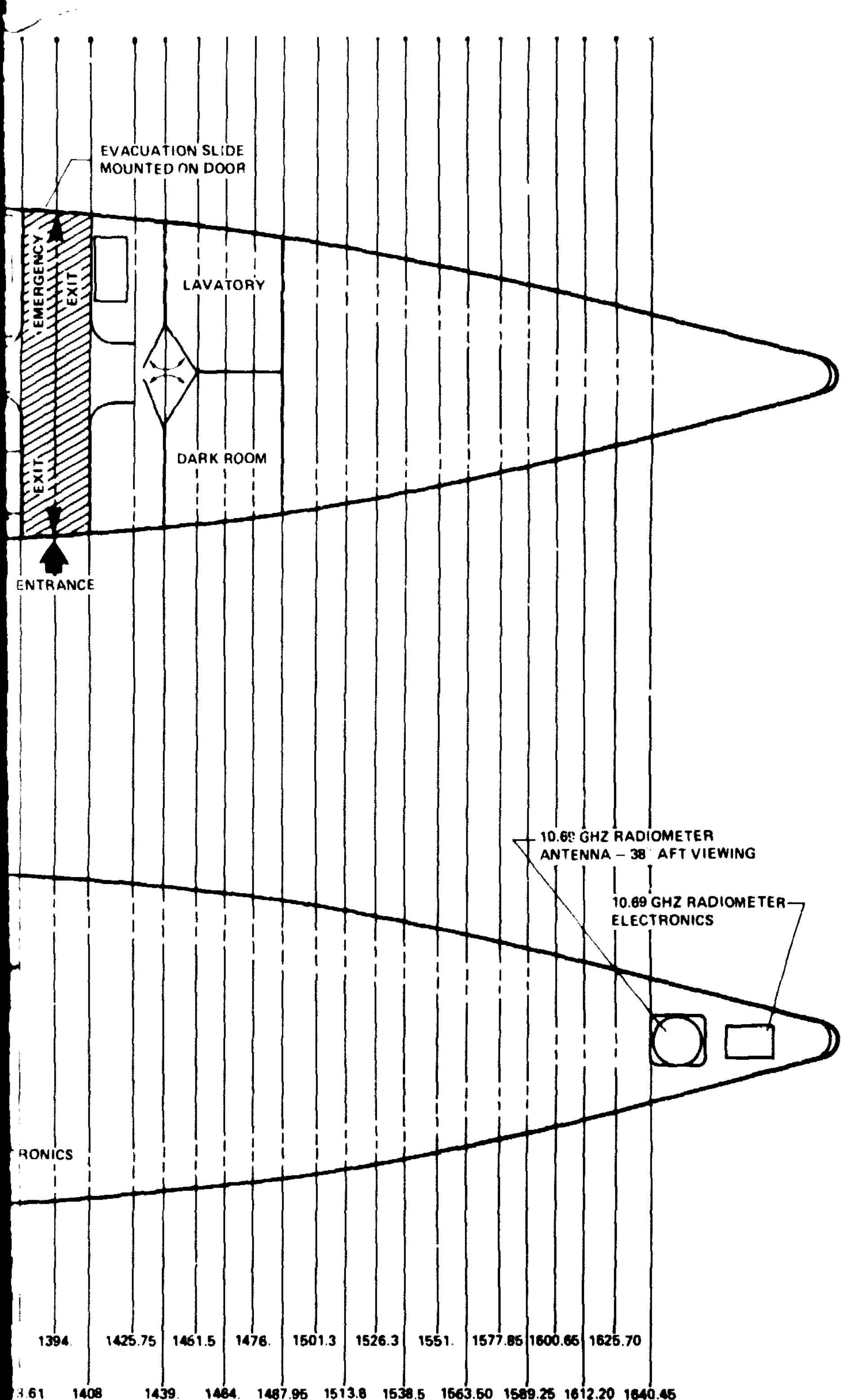
(1), (2) - PASSENGER SEATS

(A), (B) - STANDARD EQUIPMENT RACKS

(X), (Y) - LIFE SUPPORT EQUIPMENT AND LUGGAGE STORAGE

* RACKS WITH THIS SYMBOL MOUNT CCTV MONITOR ON TOP OF RACK TOTAL OF – 12.

FOLDOUT FRAME



NOTES:

ORIGINAL LAYOUT DATED 12/6/71

(A) - LAYOUT REVISED 2/17/72

(1), (2) - PASSENGER SEATS

A, B - STANDARD EQUIPMENT RACKS

(X), (Y) - LIFE SUPPORT EQUIPMENT AND LUGGAGE STORAGE

* RACKS WITH THIS SYMBOL MOUNT CCTV MONITOR ON TOP OF RACK TOTAL OF – 12.

precluded adequate warning of approaching checkpoints. In general, this problem was solved by a warning from the navigator, who had a more responsive display.

Design-Related Operational Problems

Minor inconsistencies in experiment design resulted in a few operational problems. For example, the commercially built IR scanning imager required a setting of both the velocity and the altitude to control the film advance. However, the dials provided by the manufacturer did not extend to either a high enough altitude or a high enough ground speed to be used directly, and fictitious values on ground speed and altitude had to be set to the same ratio as the actual flight conditions. (This velocity-altitude ratio was also important for determining overlap of the nadir photography.) Unfortunately, the ratio could not be readily computed by the ADDAS, which requires as input the average height above the terrain, and that value could not be obtained except at the very low altitudes at which the radar altimeter is operable.

The recorder provided for the Laser Geodolite experiment also was poorly suited for mission requirements. It was difficult to use and required liquid storage, which sloshed over the equipment during some low-level flight maneuvers.

Another example was the lack of limit switches to indicate that the viewing doors for the NIMBUS experiment were open. The experimenter had no indication of door position on his control panels. On the transit flight to Alaska, the doors were closed instead of open for a considerable time, causing some data loss.

Safety

Because transit flights involved over-ocean flying, the AIDJEX Expedition carried life rafts. Arctic survival sleds and personal kits of arctic clothing were carried for all passengers. There were no injuries requiring first-aid attention during the mission.

Documentation

Three Experimenters' Bulletins were issued for the AIDJEX Expedition. The first, dated February 7, 1972, summarized the mission objectives, listed contract personnel at the sponsoring NASA center and ASO, and included information on arctic clothing, accommodations, and flight schedules. The second bulletin, dated February 21, 1972, expanded on the mission objectives and gave a list of experiments and principal investigators. The third bulletin, dated February 25, 1972, announced a schedule delay and gave a revised schedule for the non-AIDJEX portion of the mission. No bulletins were issued after the mission was completed.

Appendix B

OCEAN COLOR EXPEDITION

One of the long-range assignments of the NASA center that sponsored the Ocean Color Expedition is to develop various experiments that will remotely measure characteristics of the earth's surface. Successful experiments with this capability are being considered for satellite application and are being developed either directly in NASA laboratories or contracted to various research and development organizations.

The complement of experiments making up the Ocean Color Expedition included several in this category. Most of the other experiments were chosen to provide a coherent, and as complete as possible, body of information concerning ocean characteristics. The remainder were "piggyback" experiments and were not designed to measure ocean characteristics. Two of these were flown on the first two flights only, and then were removed from the aircraft. A third remained aboard during the entire expedition.

Mission Objective

The objective of the Ocean Color Expedition was to evaluate the feasibility of detecting ocean color contrasts with spectrometers and spectral radiometers, as a basis for determining the sea-surface chlorophyll and sediment concentrations, and other physical or biological factors. If the concept proves feasible, the data will be used to develop specifications for an Ocean Color Imaging Spectroradiometer Experiment on the proposed Earth Observations Satellite (EOS). Specific experiments flown on the Ocean Color Expedition are listed in table B-1.

Research flights were over chosen areas of strong upwelling to provide a greater probability of ocean-color contrasts related to chlorophyll. Flights were made off the coasts of California, Massachusetts, North Carolina, and Mississippi in the United States and off the west coast of Africa near Senegal. At each of these sites, arrangements were made to obtain surface measurements of chlorophyll and sediment concentration, salinity, and sea-surface temperature. Ships of the USSR cooperated in this effort off the African coast. Ships off the east coast of the United States also made upwelling and downwelling measurements in the upper 10 meters of the ocean. One flight was made to the Sargasso Sea off the coast of Florida to sense the reflectance of near-sterile sea water.

Mission Organization and Personnel

The sponsoring NASA center management assigned the project scientist for the Ocean Color Expedition and approved the selection and funding of the primary experiments. The detailed mission planning and the arrangement of the experiments on the aircraft were accomplished by the

TABLE B-1. EXPERIMENTS FLOWN ON THE OCEAN COLOR EXPEDITION

	INSTRUMENTATION	EXPERIMENTER'S AFFILIATION	MEASUREMENT
1.	RAPID SCAN EBERT SPECTROMETER; FOV 2 X 2 AND 20 X 20 (NADIR VIEWING)	NASA SPONSORING CENTER	SPECTRAL REFLECTANCE MEASUREMENTS OF THE OCEAN SURFACE BETWEEN 0.4 AND 0.8 μm.
2.	INFRARED PHOTOMETER, FOV - 2 X 2 (NADIR VIEWING).	NASA SPONSORING CENTER	MEASUREMENT OF ATMOSPHERIC BACK SCATTERING OVER OCEAN AREAS. SPECTRAL FILTER BAND WIDTH OF 0.8 TO 1.1 μm.
3.	EBERT SPECTROMETER, FOV - 2 STERADIAN (ZENITH VIEWING).	NASA SPONSORING CENTER	INCIDENT SOLAR SPECTRAL RADIATION MEASUREMENTS BETWEEN 0.4 AND 0.8 μm.
4.	THREE MULTICHANNEL DIFFERENTIAL RADIOMETER SYSTEMS, FOV - 25 X 25 (NADIR VIEWING).	NASA-OTHER	REFLECTANCE MEASUREMENTS OF THE OCEAN SURFACE IN 14 SPECTRAL BANDS COVERING THE SPECTRAL REGION FROM 0.4 TO 0.8 μm.
5.	DIFFERENTIAL TELEVISION SYSTEM FOV - 9.6 X 7.2, 28 X 21, 70 X 52.5 (NADIR VIEWING)	NASA-OTHER	DIFFERENTIAL REFLECTANCE MEASUREMENTS OF THE OCEAN SURFACE USING BAND SPECTRAL FILTERS BETWEEN 0.38 AND 0.7 μm, AND USING POLARIZATION FILTERS.
6.	RS 310 INFRARED IMAGER, DUAL DETECTORS; 1 X 1 mrad AND 5 X 5 mrad SPATIAL RESOLUTION (± 45 LATERAL NADIR SCANNING)	OTHER GOVERNMENT AGENCY	INFRARED SURFACE RADIANCE MEASUREMENTS FOR SEA SURFACE TEMPERATURE MAPS; WAVE LENGTH REGION 7.54 TO 14.0 μm.
7.	TWO INFRARED RADIOMETERS PRT 6 SPECIAL, FOV - 2 (ZENITH VIEWING) AND PRT 5 SPECIAL, FOV - 2 (NADIR VIEWING)	OTHER GOVERNMENT AGENCY	INFRARED RADIANCE MEASUREMENTS FROM THE SEA SURFACE AND ATMOSPHERE. NADIR VIEWING, 9.5 TO 11.5 μm, SEA SURFACE TEMPERATURE; ZENITH VIEWING, 17 TO 30 μm, ATMOSPHERIC WATER VAPOR.
8.	MULTICHANNEL OCEAN COLOR SENSOR, 0.114 X 0.114 SPATIAL RESOLUTION (± 8.5 LATERAL NADIR SCANNING)	INDUSTRY	SPECTRAL REFLECTANCE MEASUREMENTS OF THE OCEAN SURFACE BETWEEN 0.4 AND 0.7 μm.
9.	SURFACE COMPOSITION MAPPING RADIOMETER; DUAL DETECTORS, 6.9 X 6.9 mrad SPATIAL RESOLUTION (± 45 LATERAL NADIR SCANNING)	NASA SPONSORING CENTER	INFRARED SURFACE RADIANCE MEASUREMENTS FOR SEA SURFACE TEMPERATURE WAVELENGTH REGION: 8.3 TO 9.3 μm WATER VAPOR BAND, 10.2 TO 11.2 μm ATMOSPHERIC WINDOW.
10.	ALUMINUM OXIDE HYGROMETERS	NASA SPONSORING CENTER	ATMOSPHERIC WATER VAPOR (DEW POINT/FROST POINT MEASUREMENTS).
11.	ATMOSPHERIC GAS SAMPLING SYSTEM	NASA-OTHER	ATMOSPHERIC CONCENTRATION MEASUREMENTS OF OZONE, TOTAL OXIDANTS AND CARBON DIOXIDE
12.	GAS SAMPLING AND ANALYZING SYSTEM *	NASA-OTHER	ATMOSPHERIC CONCENTRATION MEASUREMENTS OF OZONE, WATER VAPOR, CARBON MONOXIDE, CARBON DIOXIDE, AND NITRIC OXIDE
13.	LASER TRUE AIRSPEED SYSTEM, CO_2 LASER *	NASA-OTHER	DOPPLER BACKSCATTER FROM ATMOSPHERIC AEROSOLS, WAVELENGTH 10.6 μm.

*FLOWN ONLY ON THE MOFFETT-MOFFETT FLIGHTS.

cognizant program manager in the Airborne Science Office (ASO). Experiment installation began under direction of the ASO on June 13, 1972, and the series of 15 data flights was flown between June 28 and July 24, 1972. The duties and typical operational activities of personnel working with the experimenters on these flights are outlined below.

ASO Program/Mission Manager

In addition to the full responsibility of organizing and carrying out the flight series, the mission manager (the ASO program manager) was also official representative of the expedition to foreign governments during the period the aircraft was based outside the United States.

Assistant Mission Manager

The assistant mission manager (ASO) aided in planning and did most of the detailed work of drawing up the aircraft floor plan for the mission. During the flight series, he and the navigator handled communications between the CV-990 and the surface-truth ships, allowing the mission manager to concentrate on inflight activities.

Project Scientist

The mission's project scientist and his assistant assembled the complement of primary experiments used on this mission. The ASO manager acted as an advisor and also arranged for some of the secondary experiments. The assistant also arranged for the presence of the "surface-truth" ships in the areas to be overflown, with the exception of the Russian ships off the west coast of Africa, which was arranged through international diplomatic channels. The project scientist participated in only those flights based outside the United States; his assistant accompanied all but the last data flight.

Aircraft Facilities Manager

The facilities manager (ASO) was responsible for maintaining the onboard computer (ADDAS), three semiautomatic camera systems, and the high-speed line printer. Maintenance of this equipment required almost daily inflight troubleshooting, as well as regular maintenance between flights.

Data Systems Manager

In addition to the usual programs for aircraft flight parameters, the data systems manager wrote programs for calculating trace-gas concentrations for the air-sampling experiment (experiment 11, table B-1), chlorophyll concentration for the differential-radiometer systems (4), sun elevation and azimuth for the multichannel ocean-color sensor (8), and surface temperature for the IR radiometer experiment (7). He was responsible for the day-to-day operations of the computer during the mission, and worked closely with the experimenters to record and process data in the appropriate form.

Public Relations Officer

An Ames public relations officer handled relations with the foreign press during the interval the aircraft was based on foreign soil. He joined the flight series only on the mission's departure from the United States and left it again on its return.

Stenographer

Verbal remarks were entered into the ADDAS record by a stenographer operating an electric typewriter. ASO supplied the stenographer for the first eleven data flights and the sponsoring NASA center for the last four.

Mission Operating Procedures

Premission

In advance of the mission, the project scientist developed and assembled the desired experiments from many sources into a complementary, flyable package, and outlined a proposed flight plan. Typically, development of the ocean color experiments took place at the sponsoring NASA center with contractor assistance. Other experiments not specifically suggested by the sponsor were developed at other NASA and government laboratories.

The assistant to the project scientist (with some aid from a NASA experimenter) arranged for the presence of surface-truth ships, in consultation with the ASO mission manager. This was done primarily through contractural arrangements with oceanographic institutes having sufficient facilities to make the desired measurements.

The project scientist cleared operations over foreign territorial waters through official government channels, keeping the ASO mission manager informed of developments. (The overflight of the Russian ships off the west coast of Africa was arranged as noted, through diplomatic channels by the ASO.)

After the project scientist had arranged for as comprehensive a coverage of ocean characteristics as possible, and mutual agreement had been reached on the flight plan, the task of fitting the experiments into the CV-990 and arranging general flight operations was carried out by the ASO mission manager.

During Flight

The normal flight plan called for two passes over the surface-truth ship; the first at a high altitude (~11Km), followed as soon as possible by a second at low altitude (~0.3Km). By this means the effect of the atmospheric layer on instrument measurements was evaluated.

A major function of the project scientist during flight was that of an observer for the experimenters. From a seat in the cockpit, he made comments concerning cloud cover and sea conditions. His comments were entered into the record by the mission stenographer for possible aid in the future interpretation of data.

The observation function of project scientist was important to the mission because cloud cover frequently necessitated changes in flight plan. Although final decisions were made by the project scientist and mission manager, all scientists were generally consulted prior to such decisions. Changes in flight paths sometimes precluded ship overflights, as it was considered more desirable to obtain some data on surface characteristics and lose surface-ship verification than to overfly a cloud-covered ship.

Five experimenters aboard had technicians to help resolve equipment problems; five did not. Those scientists without technicians had experiments of secondary importance to ocean color measurements or had reliable flight-proven experiments.

All experimenters provided the stenographer with data to record. This practice frequently required on-the-spot conversion of output voltages into scientific parameters such as chlorophyll concentration and surface temperature.

Some experimenters chose to record data during every available minute of each data leg; some in as many as three forms (strip chart, analog tape, and digital tape). In contrast, at least one experimenter was aware of the difficulties in analyzing so much data and recorded only during short selected intervals. Here the experimenter's presence was important because of the desire to record only over the more interesting areas of ocean surface.

Postmission

The project scientist urged the various experimenters to submit representative data taken over foreign waters. This collection of research data, with an appropriate explanation, was to be presented to the host countries in appreciation of their hospitality. After a time interval for data analysis, the chief scientist planned to call a meeting of all Ocean Color Expedition participants to discuss and correlate results.

Interaction Between Experimenters and Mission Manager

The planning meeting before each flight provided a major opportunity for interaction between experimenters and the mission manager. Although operations generally followed the overall mission schedule, it was frequently necessary to alter flight plans in a given area because of local cloud cover. A change-of-route proposal would require discussions between the project scientist and the mission manager, and consultations with the other principal investigators. The aircraft navigator had to obtain approval of new flight paths from local air-traffic control. On more than one occasion a second alternative had to be arranged.

During the first data flight, it soon became apparent that the heavy demand for electrical power would require that certain experiments be turned off while others were in operation. After several instances when turn-on power surges tripped circuit breakers, the mission manager arranged an operating schedule that resolved the problem without significant loss of data to any experimenter. As planned, the two major power consumers were not operated after the first two flights and power scheduling was no longer a problem.

The mission manager called a debriefing meeting after each data flight. Debriefings following the first two flights were centered around power-distribution problems and minor problems of the experimenters. Subsequent debriefings were more concerned with the scheduling of work periods for the experimenters in the aircraft and the planning of future flight schedules.

Interface Requirements

The Ocean Color Expedition presented two types of interface requirements: between experiment and aircraft, and between aircraft and surface ships. The latter interface was important to the real-time operation of some experiments since the surface measurement was a true reference point for scale adjustments to flight instruments or data records. Surface data were also the base for postmission data evaluation.

The interfaces between the individual experiments and the aircraft were not especially complex. The primary elements were electrical power, equipment supports, fuselage penetrations, and the onboard computer system. Complications with electrical power (described earlier) arose primarily because total consumption was close to the maximum available. A schedule was devised that allowed experiments to be on when conditions (primarily altitude) were most favorable for successful data collection.

Experiments were installed and secured for flight safety in a routine manner. Special interfaces arose with the installation of nonstandard windows or where components or cabling penetrated the aircraft fuselage. For example, a special germanium window (provided by the experimenter) was installed to transmit 10.6μ laser radiation for the true-airspeed experiment (13). Penetration of the fuselage was necessary for the two gas-sampling experiments, and for the infrared radiometers and mappers. These experiments were designed with appropriate pressure seals so that the sensors could be exposed directly to the outer atmosphere; in three cases, hatches or windows were removed and the detector housings substituted. For one mapping radiometer (19), the detector was mounted in a special fairing attached to the underside of the aircraft and required cooling by liquid nitrogen from the rear cargo hold.

Another interface occurred between some of the experiments and the ADDAS. About one-half the experiments required the ADDAS capability of immediate data processing or recording. The others generated their own records for later evaluation.

Communications with surface ships was an important interface. Some radio interference was encountered from other ships in the area, whose more powerful transmitters blocked the

signal from the CV-990 to the surface-truth ship. However, air-to-surface communication was generally successful, and served both to establish an accurately timed flight path over the ship and to exchange data between airborne observers and the surface support group.

Experimental Equipment

Design and Construction

Observation of this mission began with the installation of equipment aboard the CV-990; as a result, early design information is not complete. Most of the primary experiments were assembled from off-the-shelf components and used special, experimenter-built switching and terminal boards to tie the components into a system (table B-2). Custom-commercial items tended to be associated with experiment sensor systems, either as passive supports and viewing-port adaptors or as active elements of the sample-inlet assembly.

The multichannel ocean-color sensor (8) is an example of alternative concepts in experiment design. The detector in this experiment was known to be highly temperature sensitive. This sensitivity could be taken into account either by maintaining the detector at constant temperature or by monitoring the temperature and making necessary corrections in postflight data analysis. (Magnetic-tape data records were sent to the home laboratory after each flight.) The second alternative was selected by the experimenter because a computer at the home laboratory was required for the data analysis anyway and could make the necessary corrections in that process.

On one experiment (9) a custom fairing that housed an infrared detector was designed and tested without sufficient concern for aircraft vibration and electrical pickup. As a result, aircraft vibrations induced noise in the detector output and the apparatus picked up 400-Hz voltages when its internal heater circuitry was activated.

The atmospheric gas-sampling experiment (11) used as little custom equipment as possible. The purpose was to test a relatively large number of commercial trace-gas samplers for possible use on commercial airliners. Alternately, the equipment was used to record the buildup of atmospheric impurity levels along the nation's airways.

Testing

Three experimenters (experiments 5, 8 and 9) received major components of their experiments only shortly before the flight series began, and had virtually no chance for preflight tests of their complete systems. Of these, only one (9) ran into serious design problems that could not be resolved during the expedition. The other two overcame minor problems and operated successfully.

The other experimenters had ample time for testing before the start of the flight series. Testing at the home laboratories is characterized in table B-3; testing at Ames is outlined in table B-4. Man-days of testing varied from less than 1 to 15 or more at both locations. Testing consisted

TABLE B-2. EXPERIMENT CHARACTERISTICS

NO.	EXPERIMENT	COMPONENT	CONSTRUCTION TYPE/SOURCE			
			OFF-THE-SHELF	CUSTOM COMMERCIAL	MODIFIED COMMERCIAL	EXPERIMENTER BUILT
1, 2, & 3	TWO EBERT SPECTROMETERS AND INFRARED PHOTOMETER (MEASURES REFLECTANCE OF OCEAN SURFACE ATMOSPHERIC BACK SCATTERING, AND INCIDENT SOLAR RADIATION) (3 EXPERIMENTS)	CONTROL PANEL		X		
		STRIP CHART RECORDER	X			
		FM TAPE RECORDER CALIBRATOR		X		
		PICOAMMETERS (3)	X			
		EBERT SPECTROMETERS (2)		X		
		TAPE RECORDERS (2)	X			
		DIGITIZER	X			
		SYNCHRONIZER	X			
		TIME CODE GENERATOR	X			
		INFRARED SENSOR	X			
4.	THREE MULTICHANNEL DIFFERENTIAL RADIOMETER SYSTEMS (MEASURE REFLECTANCE OF OCEAN SURFACE)	FIBER OPTICS BUNDLES (2)	X			
		DUAL CHANNEL FILTERS, CHOPPERS AND PRE-AMPS (2)		X		
		DUAL CHANNEL AMPLIFIERS (2)	X			
		DIGITAL VOLTMETER	X			
		LOCK-IN AMPLIFIER	X			
		STRIP CHART RECORDER	X			
5.	DIFFERENTIAL TELEVISION SYSTEM (MEASURES DIFFERENTIAL REFLECTANCE OF OCEAN SURFACE)	BLACK AND WHITE TV CAMERAS (2)	X			
		ANALOG SIGNAL PROCESSOR	X			
		DIGITAL SIGNAL PROCESSOR	X			
		COLOR TV RECEIVER	X			
		16 MM MOVIE CAMERA	X			
		VIDEO TAPE RECORDER	X			
6.	RS-310 INFRARED IMAGER (MEASURES IR SURFACE RADIANCE FOR SEA SURFACE MAPS)	DETECTOR HOUSING	X			
		CONTROL PANEL	X			
		MONITOR OSCILLOSCOPE	X			
		THERMOMETER	X			
		POWER SUPPLY	X			
		HEATER CONTROL PANEL		X		
7.	TWO INFRARED RADIOMETERS (MEASURE IR RADIANCE OF SEA AND ATMOSPHERE)	DIGITAL VOLTMETER	X			
		CONTROL PANEL				X
		THERMOMETERS (2)	X			
		SENSOR UNIT (2)	X			
8.	MULTICHANNEL OCEAN COLOR SENSOR (MEASURES REFLECTANCE AT EACH OF SEVERAL VISIBLE WAVELENGTHS)	CONTROL PANEL				X
		TAPE RECORDER	X			
		MONITOR OSCILLOSCOPE	X			
		TIMER	X			
		FUNCTION GENERATOR	X			
		POWER SUPPLIES (3)	X			
		IMAGE DISSECTOR AND OPTICS	X			
		TAPE MOTOR CONTROL	X			

TABLE B-2. EXPERIMENT CHARACTERISTICS (CONTINUED)

NO.	EXPERIMENT	COMPONENT	CONSTRUCTION TYPE/SOURCE			
			OFF-THE-SHELF	CUSTOM-COMMERCIAL	MODIFIED-COMMERCIAL	EXPERIMENTER-BUILT
9.	SURFACE COMPOSITION MAPPING RADIOMETER (MEASURES IR SURFACE RADIANCE OF SEA)	CONTROL PANEL FOR HEATER AND EXPERIMENTER POWER		X		
		CONTROL PANEL AND TEMPERATURE MONITOR		X		
		SYNCHRONIZER	X			
		EVENT COUNTER	X			
		MONITOR OSCILLOSCOPE	X			
		TIME CODE GENERATOR	X			
		TAPE RECORDER	X			
		PYLON STRUCTURE		X		
		OPTICS, SCAN SYSTEM AND DETECTOR IN PYLON		X		
		DIGITIZER	X			
10.	ALUMINUM OXIDE HYGROMETERS (MEASURE ATMOSPHERIC WATER VAPOR)	AIRSCOOPS (2)				X
		HYGROMETER SENSORS (2)	X			
		CONTROLLER	X			
		HYGROMETER ELECTRONICS		X		
		STRIP CHART RECORDER	X			
		DATA OUTPUT PANEL				X
		PORT PLATE;		X		
11.	ATMOSPHERIC GAS SAMPLING SYSTEM (MEASURES ATMOSPHERIC CONCENTRATIONS OF OZONE, TOTAL OXIDANTS, ETC.	THERMOMETER	X			
		STRIP CHART RECORDER	X			
		SIGNAL CONDITIONER	X			
		STRIP CHART RECORDERS (2)	X			
		STRIP CHART RECORDER	X			
		FLOWMETERS (3)	X			
		CO_2 DETECTOR	X			
		O_3 DETECTOR	X			
		MASS FLOWMETER	X			
		MANIFOLD		X		
		PORT PLATE		X		
		CHEMICAL OXIDIZER UNIT	X			
		PRESSURE TRANSDUCER	X			
		THERMOCOUPLE REFERENCE COMPENSATION	X			
		PUMP AND SHOCK MOUNTS	X			
		PLUMBING				X
		REGULATOR PANEL				X
		ROTAMETER	X			
		BULKHEAD PANELS				X
		AMPLIFIERS (3)	X			
		POWER DISTRIBUTION BOX	X			

TABLE B-2. EXPERIMENT CHARACTERISTICS (CONCLUDED)

NO.	EXPERIMENT	COMPONENT	CONSTRUCTION TYPE/SOURCE: OFF-THE-SHELF	CUSTOM COMMERCIAL	MODIFIED COMMERCIAL	EXPERIMENTER BUILT
12.	GAS SAMPLING AND ANALYZING SYSTEM (MEASURES ATMOSPHERIC CONCENTRATION OF OZONE, WATER VAPOR, ETC.)	PORT PLATE		X		
		CO DETECTOR			X	
		CO_2 DETECTOR	X			
		O_3 DETECTOR	X			
		H_2O DETECTOR	X			
		NO DETECTOR		X		
		PARTICULATE DETECTOR				X
		INTAKE SYSTEM				X
		RECORDING AMMETERS (7), STRIP CHART	X			
		PRESSURE METERS (2)	X			
		VACUUM PUMP	X			
		O_3 DETECTOR		X		
13.	LASER TRUE AIR SPEED SYSTEM	TRACKING GENERATOR	X			
		SPECTRUM ANALYZER	X			
		STRIP CHART RECORDER	X			
		POWER SUPPLY	X			
		CO_2 LASER	X			
		LASER POWER SUPPLY	X			
		LASER REFRIGERATOR SYSTEM	X			
		TELESCOPE	X			
		IR RETURN DETECTOR	X			
		OPTICAL WINDOW		X		

TABLE B-3. HOME LABORATORY EXPERIMENT TESTING

NO.	EXPERIMENT	TIME TESTED (MAN DAYS)	TYPE OF TESTS	TEST EQUIPMENT USED	PROBLEM HIGHLIGHTS
1, 2, & 3.	TWO EBERT SPECTROMETERS AND INFRARED PHOTOMETER	2	CALIBRATION	VOLT OHM METER (VOM), STRIP CHART, STANDARD LIGHT SOURCE	NONE
4.	THREE MULTICHANNEL DIFFERENTIAL RADIOMETER SYSTEMS	1/2	CALIBRATION AGAINST STANDARD LIGHT SOURCE	TUNGSTEN LIGHT SOURCE	NONE (EXPERIMENT DEVELOPED OVER LONG PERIOD ON OTHER AMES AIRCRAFT)
5.	DIFFERENTIAL TELEVISION SYSTEM	10	PERFORMANCE AND RELIABILITY	NONE	OVERHEATING OF ELECTRONICS. LATE DELIVERY OF MAJOR COMPONENT PREVENTED TESTS OF COMPLETE SYSTEM.
6.	RS-310 INFRARED IMAGER	0	STORED AT AMES, NO TESTING AT HOME BASE	NONE	NONE
7.	TWO INFRARED RADIOMETERS	1/2	CALIBRATION	VOM, STANDARD TEMPERATURE SOURCE	NONE
8.	MULTICHANNEL OCEAN COLOR SENSOR	6	CALIBRATION	VOM, STANDARD TEMPERATURE CHAMBER	LATE DELIVERY OF MAJOR COMPONENT PREVENTED TESTS OF COMPLETE SYSTEM.
9.	SURFACE COMPOSITION MAPPING RADIOMETER	10	NONE ON COMPLETE SYSTEM	NOT KNOWN	NONE KNOWN. LATE DELIVERY OF MAJOR COMPONENTS
10.	ALUMINUM OXIDE HYGROMETER	1/2	CALIBRATION	ENVIRONMENTAL CHAMBER (PRESSURE, TEMPERATURE)	RESPONSE TIME TOO LENGTHY; RE-DESIGN DUCTING CONTROLLING AIR TO DETECTOR.
11.	ATMOSPHERIC GAS SAMPLING SYSTEM	20	CALIBRATION	STANDARD GAS SAMPLES	NONE
12.	GAS SAMPLING AND ANALYZING SYSTEM	10	OPERATION & CALIBRATION	STANDARD GAS SAMPLES	NONE
13.	LASER TRUE AIRSPEED SYSTEM	3	LASER POWER, FREQUENCY, STABILITY & OPTICS PERFORMANCE	POWER METER, HEAT PROBES, SPECTROMETER, OPTICAL EQUIPMENT	NONE

TABLE B-4. EXPERIMENT PREFLIGHT TESTING AT AMES

NO.	EXPERIMENT	TEST EFFORT		PROBLEM HIGHLIGHTS
		TYPE OF TEST	TIME TESTED (MAN-DAYS)	
1, 2 & 3.	TWO EBERT SPECTROMETERS AND INFRARED PHOTOMETER	OPERATION	1/2	NONE
4.	THREE MULTICHANNEL DIFFERENTIAL RADIOMETER SYSTEMS	CALIBRATE AGAINST SUN	1/2	NONE
5.	DIFFERENTIAL TELEVISION SYSTEM	PERFORMANCE TEST	15	REPLACED TV MONITOR
6.	RS-310 INFRARED IMAGER	OPERATION	1/4	NONE
7.	TWO INFRARED RADIOMETERS	OPERATION	1/4	NONE
8.	MULTICHANNEL OCEAN COLOR SENSOR	TEMPERATURE CALIBRATED, STANDARD VOLTAGE	6	NONE
9.	SURFACE COMPOSITION MAPPING RADIOMETER	PERFORMANCE TEST	10	SIGNAL NOISE FROM AIRCRAFT VIBRATION. ELECTRICAL PICKUP FROM HEATER. NEITHER PROBLEM RESOLVED DURING PREFLIGHT TESTING.
10.	ALUMINUM OXIDE HYGROMETERS	OPERATION	1/4	NONE
11.	ATMOSPHERIC GAS SAMPLING SYSTEM	CALIBRATE	2	CO_2 DETECTOR VERY NOISY. REPAIR DELAYED ONE WEEK.
12.	GAS SAMPLING AND ANALYZING SYSTEM	OPERATION	1/4	LATE INSTALLATION
13.	LASER TRUE-AIRSPEED SYSTEM	PERFORMANCE OF LASER	2	NONE

largely of calibration against standard signal sources. For example, the Ebert spectrometers and the multichannel ocean-color sensor (MOCS) used incident radiation at various wave lengths; the infrared radiometers used standard temperature sources; the gas sampling experiments used standard gas samples. In contrast, tests of the differential television experiment (5), which used twin cameras, consisted only of verification of boresighting of the cameras for picture coincidence.

As installation neared completion, all experimenters checked their equipment for electrical interference from adjacent experiments or aircraft systems. No major interference problems were noted, although at this time the power-consumption problem was first encountered.

Only on one experiment (8) was a real effort made to get some of the data records back to the home laboratory for analysis while the flight series was in progress. The resulting feedback led to modifications of experimental procedure that subsequently provided better data records.

Experiment Reliability

Thirteen different experiments were flown on all or a portion of the flights of the Ocean Color Expedition. Most of the experimenters had flight experience, as shown in table B-5. Both new and repeat experimenters made minor operational mistakes during the first few flights. For example, a new man might run out of film while a repeat experimenter might fail to turn on a strip recorder. During the early phase of the mission the experimenter adapted to the routine of flight operations and set up his own experiment operation procedures.

Ocean color experiment problems and their impact are summarized in table B-6. Recurring problems are listed only once unless the method or location of repair was different (e.g. inflight vs. ground repair). The first-time surface composition mapping radiometer (9) was plagued with vibrational noise and electrical pickup problems that prevented its operation on four flights; in contrast, the first-time MOCS experiment (8) had no serious problems. Because of the short observation period, the airborne gas sampling and laser true-airspeed systems provided few reliability data.

Most problems had little or no impact on the data. Several were mechnical in nature and directly traceable to a very rough airport runway at one of the remote bases. Another rather uncommon source of trouble was water vapor condensing on aircraft and apparatus surfaces during descent from high altitudes in humid climates. If the last two sources are excluded, problem incidence varied roughly with equipment type: off-the-shelf components accounted for 77 percent of the equipment and about 75 percent of the problems; custom-commercial components, 13 percent and 25 percent, respectively; and experimenter-built components, 9 percent and 0 percent, respectively.

Safety

ASO procedures included a review of experiment installations by the Airworthiness and Flight Safety Review Board and inspection of all installed equipment. The preflight meeting of the

TABLE B 5. EXPERIMENTER EXPERIENCE

NO.	EXPERIMENT	FIRST TIME EXPERIMENTER	FIRST TIME EXPERIMENT	REPEAT EXPERIMENTER	REPEAT EXPERIMENT
1,2, & 3.	TWO EBERT SPECTROMETERS AND INFRARED PHOTOMETER (1 SCIENTIST, 2 TECHNICIANS)			X	X
4.	MULTICHANNEL DIFFERENTIAL RADIO-METER SYSTEMS (1 SCIENTIST)			X	X
5.	DIFFERENTIAL TELEVISION SYSTEM (1 SCIENTIST)			X	X
6 & 7	RS-310 INFRARED IMAGER, INFRARED RADIOMETERS (1 SCIENTIST)			X	X
8.	MULTICHANNEL OCEAN COLOR SENSOR (1 SCIENTIST, 2 TECHNICIANS)	X	X		
9.	SURFACE COMPOSITION MAPPING RADIOMETER (1 SCIENTIST, 1 TECH-NICIAN)		X	X	
10.	ALUMINUM OXIDE HYGROMETERS (1 SCIENTIST)			X	X
11.	ATMOSPHERIC GAS SAMPLING SYSTEM (1 SCIENTIST)	X	X		
12.	GAS SAMPLING AND ANALYZING SYSTEM (1 SCIENTIST, 1 TECHNICIAN)		X	X	
13.	LASER TRUE-AIRSPEED SYSTEM (1 SCIENTIST, 1 TECHNICIAN)			X	X

TABLE B 6 EXPERIMENT PROBLEMS DURING THE OCEAN COLOR EXPEDITION

NC	EXPERIMENT (NEW OR REPEAT)	PROBLEM	IMPACT ON DATA		
			NONE	LIMITED	SEVERE
1,2 &3	TWO EBERT SPECTROMETERS AND INFRARED PHOTOMETER (R)	TIME CODE GENERATOR MALFUNCTIONED		X	
		CHART PEN CLOGGED	X		
		WIRES TO STRIP CHART HAD LOOSE CONNECTION	X		
		CHART PEN CLOGGED	X		
		60 CYCLE NOISE PICKUP	X		
4.	MULTICHANNEL DIFFERENTIAL RADIOMETER SYSTEMS (R)	DESIGN ERROR SIGNAL COULD NOT BE ATTENUATED			X
		POTENTIONMETER BROKEN	X		
5.	DIFFERENTIAL TELEVISION SYSTEM (R)	EQUIPMENT OVERHEATED			X
		LOOSE BNC CONNECTION	X		
		CONDENSATION ON WINDOW		X	
6.	RS-310 INFRARED IMAGER (R)	NONE			
7.	INFRARED RADIOMETERS (R)	WATER CONDENSATION JAMMED CHOPPER			X
8.	MULTICHANNEL OCEAN COLOR SENSOR (N)	MISALIGNED OPTICS WEAKENED SIGNAL		X	
		SLOW STARTING TAPE RECORDER	X		
		RECORDER STARTING SURGE TRIPPED POWER BREAKER	X		
9.	SURFACE COMPOSITION MAPPING RADIOMETER (N)	ELECTRICAL NOISE PICKUP			X
		VIBRATIONAL NOISE PICKUP			X
		INOPERATIVE PROTECTING DOOR		X	
		TIME CODE GENERATOR MALFUNCTIONED		X	
		DIGITIZER FAILED		X	
10.	ALUMINUM OXIDE HYGROMETERS (R)	CONDENSED WATER FROZE SENSOR			X
11.	ATMOSPHERIC GAS SAMPLING SYSTEM (N)	LOOSE WIRE TO ADDAS PRODUCED WRONG DATA	X		
		CO_2 SENSOR MALFUNCTION DUE TO VIBRATION		X	
		PRESSURE VALVE NOT HOLDING		X	
12.	GAS SAMPLE AND ANALYZING SYSTEM (N)	NONE			
13.	LASER TRUE AIRSPEED SYSTEM (R)	NONE			

Airworthiness and Flight Safety Review Board is a major factor in the perfect safety record of this program. Typically, all elements of the proposed flight series that could even remotely impair flight safety are considered. One experiment that aroused concern was the surface composition mapping radiometer (9); major components of the experiment were mounted in an external fairing along with the infrared detector, which was cooled by liquid nitrogen. Both the airworthiness of the fairing and the fail-safe devices incorporated into the detector cryogenic system were evaluated. The only other experiment considered a possible hazard was the laser true-airspeed system (13), which used a high-power infrared laser beam (approximately 12 watts). Concern was centered on the accidental placement of persons or flammable objects in the path of the beam. Precautions to prevent this problem were shown to be sufficient.

On one flight, one of the many layers of the pilot's window shattered while the aircraft was at an altitude of 10.7 Km. The pilot immediately began descent and jettison of fuel commensurate with returning to base. The window was later replaced with an onboard spare. Another flight was delayed five hours while a malfunctioning oxygen valve was replaced.

Documentation

The first formal announcement of an Ocean Color Expedition was made by memorandum from the sponsoring NASA center on December 3, 1971. From this point, coordination between the sponsor, ASO, and the various individual experimenters was carried out by personnel visit or by telephone.

On June 5, 1972, the ASO mission manager issued the first Experimenters' Bulletin, which listed the specific ASO personnel responsible for various aspects of the mission and a tentative flight schedule. A second bulletin was issued on June 23, 1972, specifying the goals of the mission, including the specific areas of ocean to be overflown, the persons responsible for obtaining "surface-truth" measurements in the various areas, and a detailed installation and flight schedule. This bulletin included the following additional information:

1. The address of all accommodations to be utilized during this mission.

2. A list of experimenters with brief descriptions of their experiments.

3. A list of immunization requirements for the foreign countries to be visited.

4. Information on insurance coverage during NASA flights.

A third Experimenters' Bulletin was issued on July 3, 1972. As a result of an agreement between the United States and USSR, it was planned that the CV-990 aircraft would overfly Russian oceanographic ships stationed near 8° north latitude, 21° west longitude. This forced a change in flight schedule and location of the CV-990 operating base. Last-minute arrangements were made to operate from Dakar, Senegal. These changes were included in the third bulletin only two days before the CV-990 was scheduled to leave Ames.

With one exception, formal documentation was not required by the sponsoring center or the ASO during the planning or the execution of the mission. The exception was a NASA contractor who was required to document the MOCS experiment (8).

The chief scientist planned a meeting of experimenters at an appropriate time after the completion of the mission for reporting and evaluation of the scientific results.

Appendix C

AUGUST 1972 MISSION

Mission Objectives

The CV-990 August 1972 Mission involved programs for the development of instrumentation to detect clear-air turbulence and to sample trace amounts of certain gases in the atmosphere. Supporting experiments measured atmospheric temperature, water-vapor content, spectra of upper atmosphere gases, and incident solar radiation. The mission experiments and their objectives are given in table C-1; all nine flights were locally based.

This mission represented the first CV-990 flight test of the clear-air turbulence (CAT) experiment, which utilizes backscatter from atmospheric particles illuminated by a laser to detect turbulent air ahead of the aircraft. The atmospheric sampling program (ASP) utilizes the CV-990 as a test platform for flights of commercial trace-gas samplers with the ultimate goal of placing automatic gas samplers on commercial jetliners. The stratospheric air sampling (SAS) program tests equipment designed for eventual use on a higher-flying, earth-resources aircraft.

By special request of NASA Headquarters just a few days before the flight series began, plans were changed to include underflights of the Earth Resources Technology Satellite (ERTS) on two passes along the California coast. The objective was to aid the interpretation of satellite pictures through comparisons of aircraft and satellite results. To meet this requirement, an experiment from the Ocean Color Expedition (appendix B) was flown that involved an upward-looking Ebert spectrometer and two downward-looking cameras. The equipment, which had been in storage at Ames since the last mission, was quickly assembled and installed on the aircraft in time for the sixth flight of the series. The first of the two planned special ERTS flights was successful; the second was cancelled because of poor visibility.

The experiments for the August 1972 Mission represented different aspects of meteorology with the common objective of operation at relatively high altitudes. Thus, it was expected that while optimum flight profiles might differ, observing conditions would overlap sufficiently to permit most experiments to operate on every flight. This planning strategy was successful except for the CAT experiment, which seldom gave usable signals at altitudes above 6 Km where the SAS and far-infrared sky emission (FIR) experiments operated best.

Mission Organization and Personnel

At a formal experimenters' meeting on August 8, 1972, the two mission managers presented the overall mission objectives and scheduled flight procedures. After every flight, the mission manager held a debriefing to review with the experimenters the events of that day's flight, any operational problems he or the experimenters may have noted, and plans for the next flight. On

TABLE C-1. EXPERIMENTS FLOWN ON THE AUGUST 1972 MISSION

INSTRUMENTATION	MEASUREMENT
PRIMARY SENSORS	
1. STRATOSPHERIC AIR SAMPLING (SAS), COMMERCIAL GAS DETECTORS	TRACE O_3, H_2O, CO, CO_2 IN EARTH'S ATMOSPHERE
2. ATMOSPHERIC SAMPLING PROGRAM (ASP), COMMERCIAL GAS DETECTORS	TRACE AMOUNTS OF O_3, NO_x, CO, CO_2, SO_2 IN EARTH'S ATMOSPHERE
3. CLEAR AIR TURBULENCE (CAT), LASER OPTICAL RADAR	DETECTION OF CLEAR AIR TURBULENCE USING 10.6 μ LASER
SUPPORTING SENSORS	
4. FAR INFRARED SKY EMISSION, IR SPECTROMETER	SPECTRA OF UPPER ATMOSPHERIC GASES BETWEEN 0.1 AND 2 mm
5. RAPID SCAN EBERT SPECTROMETER, ZENITH VIEWING, TWO NADIR VIEWING CAMERAS (FOR ERTS UNDERFLIGHTS)	INCIDENT SOLAR SPECTRAL RADIATION, MEASUREMENTS BETWEEN 0.5 AND 0.9 μ; CLOUD COVER
6. TWO INFRARED RADIOMETERS, ZENITH AND HORIZONTAL	INFRARED MEASUREMENT OF WATER VAPOR OVERBURDEN (8 TO 30 μ) AND TEMPERATURE OF AIR AT AIRCRAFT'S ALTITUDE (15 μ).
7. ALUMINUM OXIDE (AL_2O_3) HYGROMETER	ATMOSPHERIC WATER VAPOR (DEW POINT/FROST POINT)

several occasions an additional briefing was held immediately before flight. The absence of the aircraft pilots from the sessions resulted in minor communication gaps and experimental problems, as when the CAT experimenter requested a constant-attitude dive that was executed as a constant-speed dive.

Duties and typical operational activities of personnel working with the experimenters are outlined below.

Mission Manager

On flights where the CAT experiment was the primary activity, the aircraft facilities manager also acted as mission manager. On the other flights, the regular mission manager (the ASO program manager) was in charge, and the facilities manager returned to his usual flight assignment of monitoring and maintaining the operation of the airborne computer system (ADDAS) and other experiment support systems.

Data flights characteristically involved short runs of 10 minutes at a fixed altitude, followed by a change in altitude and a return along the same path. Scheduled plans were often changed in flight to facilitate the acquisition of data; at the completion of each short segment, the cognizant experimenter and the mission manager discussed changes desirable for the next run.

As noted, the mission manager conducted briefings and debriefings for each flight. On special occasions (e.g., a change in flight plans), a separate briefing session covered the objectives and schedule of the day's prime experiment for the upcoming flights. Otherwise, the flight review and planning activities were combined into one meeting.

Project Scientist

The primary experimenter of the CAT, ASP, or SAS experiment assumed the role of project scientist, depending on which of these experiments was the lead for that day. Prior to flight, the project scientist established requirements for the runs to be scheduled for his experiment. During flight, deviations from the scheduled runs were requested of the mission manager, on the basis of data obtained in previous runs. Requests for simple deviations from the flight plans, such as changes in altitude, were directly communicated to the pilot by the manager; requests for extensive deviations consisting, for example, of a different heading for a long time period, were routed to the navigator for confirmation before being transmitted to the pilot.

Data Systems Manager

Before the start of the flight series, the data systems manager collected the data-recording and -processing requirements, sensor calibration curves, and associated information from the experimenters, so that he could develop the software required for real-time data reduction. The principal inflight duties of the manager were to ensure that the ADDAS system was properly receiving, processing, and recording the experimenters' data, and to enter pertinent comments and

other explanatory information into the magnetic memory. After each flight, he distributed printouts of the data to all experimenters, and copies of the magnetic tape record to those experimenters desiring additional information not provided on the data printouts.

The Role of the Experimenter

The experimenter is responsible for experiment design, construction, testing, operation, and data reduction. Only the test and operational aspects of this responsibility are reported here; there was no opportunity to observe directly the design and construction portions of experiment development.

The ASO mission manager was the prime contact between the experimenter and Ames support groups. Whenever the experimenter wanted information or help, or had information for the ASO, he would receive or send it through the mission manager. During the flight series, all day-to-day requests for changes in flight plan or aircraft parameters were referred to the mission manager for decision.

The inflight operation of equipment was well documented. Each experimenter tended his own equipment nearly full time, usually not speaking to anyone other than the mission manager. Occasionally, two people with similar experiments exchanged results; for example, the SAS and ASP experimenters compared data, as did the FIR and zenith radiometer experimenters. Interaction between experimenters and the ADDAS operator varied from none to often, depending on the amount of data recording and processing involved. The experimenters very seldom requested any help from the flight crew.

Interface Requirements

Each experimenter provided information on the power requirements, weight, and dimensions of his equipment, noting any special requirements as well. From this information, the mission manager drew up a floor plan of the aircraft showing the placement of each experiment. A copy of this floor plan was given to each experimenter for his comments.

Electrical power was not a major problem, although some scheduling was required. On occasion a circuit breaker tripped, and experiments had to be rearranged on different circuits. Observations were scheduled so that several of the large power users either were not operated on every flight or operated only part-time during a flight. For example, SAS and FIR operated only at high altitude, while CAT operated at low altitude.

The full-size and low-boy standard equipment racks were used by all the experimenters. Some experiments used large or odd-shaped instruments, which were mounted on top of the racks. The FIR experiment, for example, had an interferometer that was mounted on top of a full-size rack; the CAT laser was mounted across two low-boy racks (figure C-1).

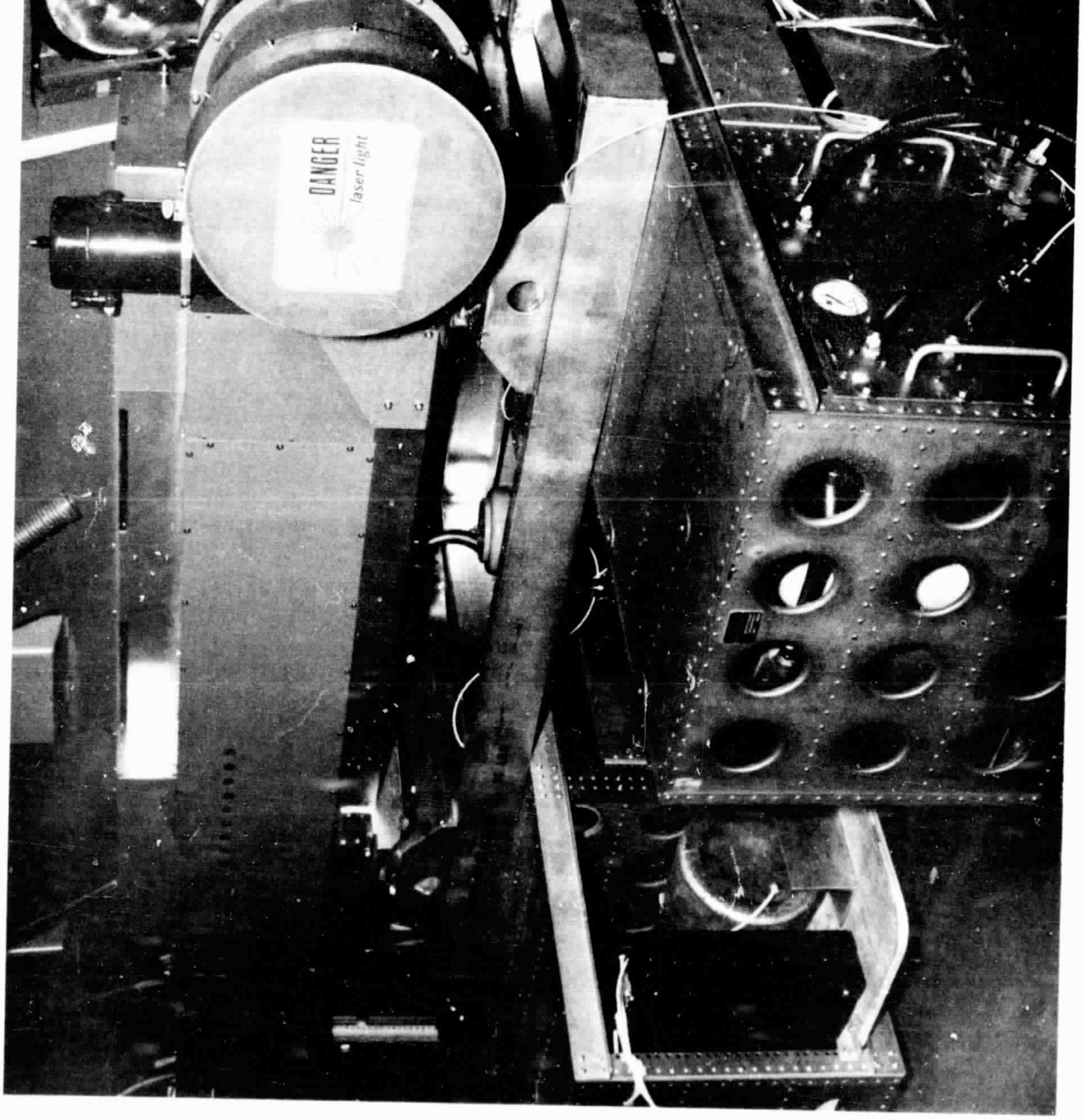


Figure C-1 — Clear air turbulence (CAT) experiment in CV–990 aircraft.

Access to the space outside the aircraft was accomplished by replacing standard passenger or viewing-port windows with special windows, air intakes, or support plates. In the case of the CAT experiment, a fairing 6 feet long (supported in several window openings and one door opening) was designed by Ames engineers and constructed in the metal shop at Ames (figure C-2). In all the other experiments, the mounting of the exterior components was simpler. The FIR polyethylene window replaced the regular window in one of the zenith ports, while the SAS, ASP, and hygrometer experiments used standard metal hatches in which air intakes were mounted. Sensors for the infrared radiometers and Ebert spectrometer were mounted in standard hatches fabricated at Ames.

The experimenters used the intercom system continuously. Most of these conversations were with personnel assisting in experiment operation; occasionally, an experimenter talked to the mission manager or to the principal investigator of a similar or supporting experiment. SAS and ASP experimenters exchanged data on jointly monitored gases; SAS, FIR, and hygrometer operators exchanged data on water vapor. Because of the uniqueness of their experiment, the six scientists and technicians working the CAT experiment had little contact with the other experimenters.

The ADDAS computer was used extensively. The raw-data input to ADDAS was typically a voltage signal from a sensor, which was converted into a meaningful quantity using a stored calibration curve or conversion factor supplied by the experimenter. The experimenters arranged with the ADDAS operator before a flight for a printout of experimental data and pertinent aircraft flight parameters.

Experimental Equipment

Design and Construction

As a group, the experimenters on the August 1972 Mission used predominantly off-the-shelf equipment, with the remainder about evenly divided among custom-commercial, modified-commercial, and experimenter-built components (table C-2). Equipment was designed in accordance with the safety and installation requirements of the CV-990 Experimenters' Handbook. Most of the equipment was built so that it could be mounted in, or on top of, a standard CV-990 equipment rack. The CAT experiment was the most complicated, with a laser and a telescope mounted across two standard low-boy racks (figure C-1). The telescope light-gathering system was housed in a special fairing designed by Ames engineers in consultation with the contractor who built the experiment (figure C-2).

Testing

Tests performed at the experimenters' home laboratories are summarized in table C-3; most experiments did not undergo rigorous, elaborate testing, although several experimenters would have conducted a more extensive test program if their manpower and funding had permitted. Actually, most of the tests were for either operational or calibration purposes.

Preflight testing at Ames is indicated in table C-4. These again were calibration and operational tests made by the experimenters, using their own test equipment.

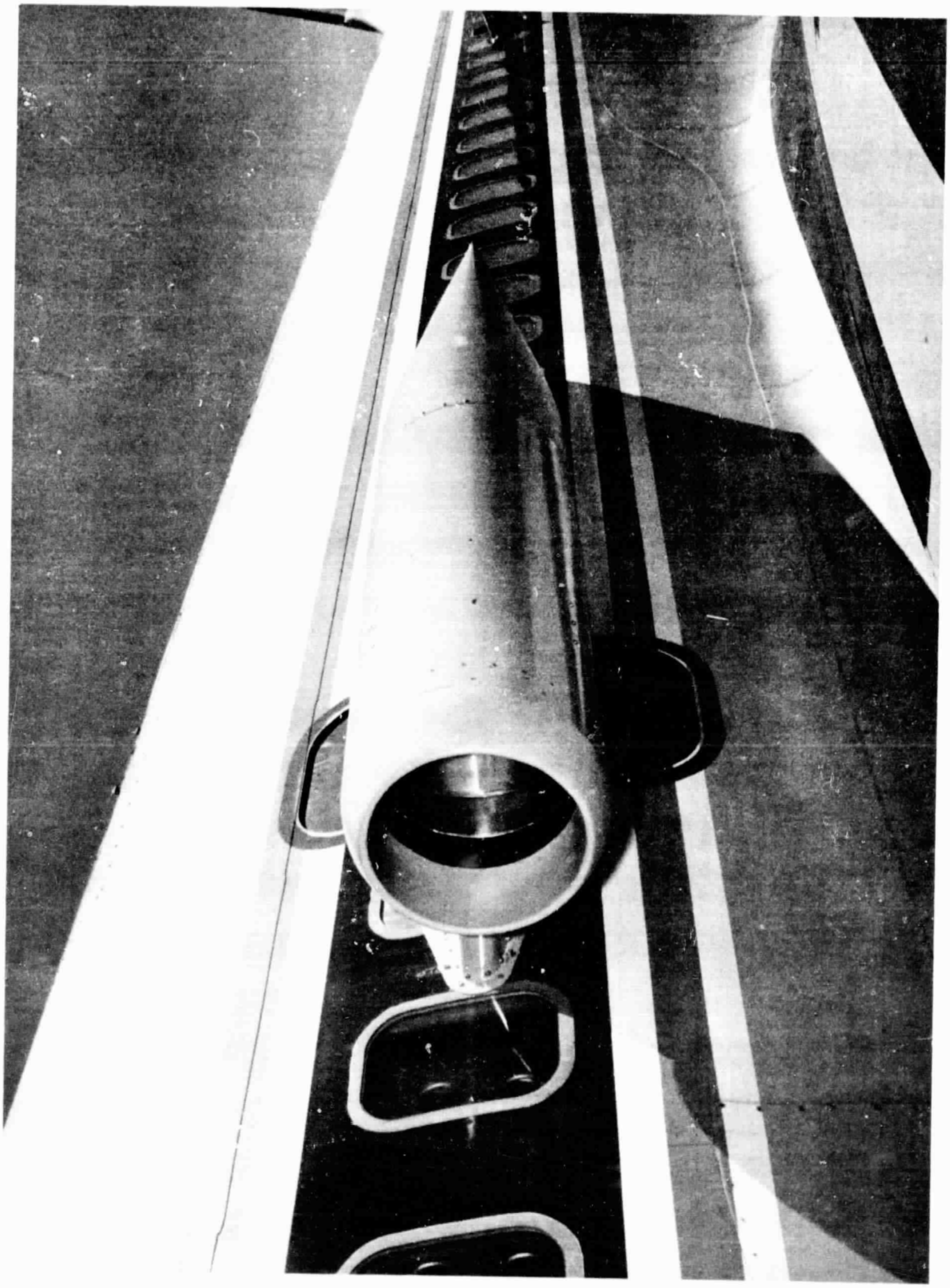


Figure C-2 — External fairing of CAT experiment.

TABLE C-2. EXPERIMENT CHARACTERISTICS

EXPERIMENT	COMPONENT	CONSTRUCTION TYPE/SOURCE			
		OFF-THE-SHELF	CUSTOM-COMMERCIAL	MODIFIED-COMMERCIAL	EXPERIMENTER-BUILT
1. STRATOSPHERIC AIR SAMPLING (SAS)	CO DETECTOR			X	
	CO_2 DETECTOR	X			
	O_3 DETECTOR	X			
	H_2O DETECTOR	X			
	NO DETECTOR		X		
	PARTICULATE DETECTOR				X
	O_3 DETECTOR	X			
	INTAKE SYSTEM				X
	RECORDING AMMETERS (7), STRIP CHART	X			
	PRESSURE METERS (2)	X			
	VACUUM PUMP	X			
2. ATMOSPHERIC SAMPLING PROGRAM (ASP)	THERMOMETER	X			
	AMMETER	X			
	STRIP CHART RECORDER	X			
	SIGNAL CONDITIONER (3)	X			
	STRIP CHART RECORDER (2)	X			
	STRIP CHART RECORDER (3)	X			
	FLOW METERS AND PANEL (3)	X			
	CO_2 DETECTOR	X			
	O_3 DETECTOR	X			
	O_3 DETECTOR	X			
	STRIP CHART RECORDER	X			
	MASS FLOWMETER	X			
	MANIFOLD		X		
	O_3 DETECTOR	X			
	NO, NO_2, NO_X ANALYZER	X			
	FLOWMETER	X			
	TOTAL OXIDANT DETECTOR		X		
	PRESSURE TRANSDUCER	X			
	THERMOCOUPLE REFERENCE	X			
	PUMP AND SHOCK MOUNTS	X			
	PLUMBING SYSTEM				X
	VACUUM PUMP	X			
	ROTAMETER	X			
	BULKHEAD AND SPANGAS PANELS				X
	AMPLIFIERS (16)	X			
	POWER DISTRIBUTION BOX (2)	X			
	ETHYLENE BOTTLE	X			
	OXYGEN BOTTLE	X			
	CO MONITOR	X			
	SO_2 MONITOR	X			

TABLE C-2. EXPERIMENT CHARACTERISTICS (CONTINUED)

EXPERIMENT	COMPONENT	CONSTRUCTION TYPE/SOURCE			
		OFF-THE-SHELF	CUSTOM-COMMERCIAL	MODIFIED-COMMERCIAL	EXPERIMENTER-BUILT
3. CLEAR AIR TURBULENCE (CAT)	POWER METER			X	
	POWER AMPLIFIER AND MODULATOR		X		
	HIGH VOLTAGE POWER SUPPLY			X	
	OSCILLOSCOPE	X			
	SYNCHRONIZER			X	
	DETECTOR CONTROL PANEL		X		
	REGULATOR HIGH VOLTAGE SUPPLY			X	
	HIGH VOLTAGE POWER SUPPLY (10 kv)			X	
	SPECTRUM ANALYZER (2)	X			
	ANALYZER DISPLAY (2)	X			
	OSCILLOSCOPE	X			
	BNC BOARD AND SHUTTER CONTROL				X
	BNC TERMINAL BOARD				X
	DIGITAL TAPE RECORDER			X	
	POLAROID CAMERA			X	
	POLAROID CAMERA	X			
	OSCILLOSCOPE	X			
	RF GENERATOR	X			
	OSCILLOSCOPE AND CONTROL	X			
	LOW VOLTAGE POWER SUPPLY (4)			X	
	RECORD CHANNEL		X		
	IF PROCESSING UNIT		X		
	PULSE WIDTH AND FILTER CHANNEL		X		
	CAMERA CONTROL PANEL				X
	SEQUENCE OSCILLOSCOPE	X			
	SEQUENCE CAMERA	X			
	TAPE RECORDER	X			
	FAIRING AND OPTICS		X		
	LASER POWER AMPLIFIER		X		
	30 cm CASSEGRAIN TELESCOPE		X		
	REFRIGERATOR	X			
	CO_2 SUPPLY SYSTEM	X			
	VACUUM PUMP	X			
	VIDEO TAPE RECORDER	X			
	TV CAMERA	X			
4. FAR-INFRARED SKY EMISSION (FIR)	POLYETHELYNE WINDOW	X			
	INTERFEROMETER	X			
	MIRROR DRIVE	X			
	PHASE LOCK AMPLIFIER	X			
	VOLTMETER	X			
	STRIP CHART RECORDER	X			
	OSCILLOSCOPE	X			
	TAPE RECORDER	X			
	BOLOMETER				X
	DEWAR				X

TABLE C-2. EXPERIMENT CHARACTERISTICS (CONCLUDED)

EXPERIMENT	COMPONENT	CONSTRUCTION TYPE/SOURCE			
		OFF-THE-SHELF	CUSTOM-COMMERCIAL	MODIFIED-COMMERCIAL	EXPERIMENTER BUILT
5. RAPID SCAN EBERT SPECTROMETER (FOR ERTS UNDER-FLIGHTS)	CONTROL PANEL		X		
	STRIP CHAFT RECORDER (4 CHANNEL)	X			
	FM TAPE RECORDER CALIBRATOR		X		
	PICO AMMETER	X			
	EBERT SPECTROMETER		X		
	TAPE RECORDER	X			
	TAPE RECORDER	X			
	DIGITIZER	X			
	SYNCHRONIZER	X			
	TIME CODE GENERATOR	X			
6. INFRARED RADIOMETERS	DIGITAL VOLTMETER	X			
	CONTROL PANEL				X
	THERMOMETER	X			
	STRIP CHART RECORDER	X			
	SENSOR UNITS (2)			X	
7. AL_2O_3 HYGROMETERS	AIR SCOOP (2)			X	
	HYGROMETERS (2)	X(1)	X(1)		
	HYGROMETER MOUNTING (2)		X(1)		X(1)
	POWER SUPPLY	X			
	HYGROMETER ELECTRONICS				X
	STRIP CHART RECORDER	X			
	DATA OUTPUT PANEL				X

TABLE C-3. HOME BASE EXPERIMENT TESTING

EXPERIMENT	TIME TESTED (MAN-DAYS)	TYPE OF TEST	TEST EQUIPMENT	TEST PROCEDURES
1. STRATOSPHERIC AIR SAMPLING (SAS)	120	CALIBRATION	CALIBRATION GASES	CALIBRATE INSTRUMENTS USING GASES OF KNOWN CONCENTRATIONS.
2. ATMOSPHERIC SAMPLING PROGRAM (ASP)	20	CALIBRATION AND DRIFT	KNOWN GAS CONCENTRATIONS	DILUTE PURE GASES TO PPB LEVELS; CHECK CALIBRATION OF GAS DETECTORS WITH THESE GASES. CHECK DRIFT OF SYSTEM WITH TIME.
3. CLEAR AIR TURBULENCE (CAT)	300 10	OPERATIONAL FLIGHT SIMULATION (NOISE INDUCED VIBRATION)	BELT SANDER TAPE RECORDER	EQUIPMENT INSPECTED BY CONTRACTOR AND COMMERCIAL UNITS MADE MORE DURABLE FOR FLIGHT MEASURE DOPPLER SHIFT OF MOVING BELT. RECORD AIRCRAFT NOISES AND REPLAY THEM NEAR LASER.
4. FAR INFRARED SKY EMISSION (FIR)	5 25	MECHANICAL SIMULATION	SHAKE TABLE LIQUID HELIUM	USE ONE DEWAR AS REFERENCE AND ONE AS SKY SIGNAL SIMULATOR.
5. EBERT SPECTROMETER (FOR ERTS UNDERFLIGHTS)	0	NONE	NONE	NONE
6. RADIOMETERS	3 (OLD) 7-10 (NEW)	CALIBRATION FLIGHT SIMULATION	CALIBRATED TEMPERATURE SOURCES ENVIRONMENTAL CHAMBER	CALIBRATE RADIOMETERS USING FIVE DIFFERENT TEMPERATURE SOURCES FROM 60 K TO 330 K; CALIB. CHANGES IN DETECTORS WITH TIME. RADIOMETERS IN ENVIRONMENTAL CHAMBER SIMULATING FLIGHT TEMPERATURE, PRESSURE.
7. AL_2O_3 HYGROMETER	7 7	CALIBRATION CHECKOUT		CHECK MANUFACTURER'S CALIBRATION OF SENSOR. NASA PERSONNEL CHECKED OUT ELECTRONICS.

TABLE C-4. EXPERIMENT PREFLIGHT TESTING AT AMES

EXPERIMENT	TEST EFFORT					TEST PROCEDURES
	TYPE OF TEST	TIME TESTED (MAN-DAYS)	TEST EQUIPMENT FURNISHED	TEST FAILURE FREQUENCY	AMES SUPPORT	
1. STRATOSPHERIC AIR SAMPLING (SAS)	CALIBRATION	2	NONE	NONE REPORTED	NONE	USE CALIBRATION GASES TO CHECK BACKGROUND SENSITIVITY
2. ATMOSPHERIC SAMPLING PROGRAM (ASP)	CALIBRATION OPERATIONAL	2				CHECK CALIBRATION WITH KNOWN CONCENTRATION GASES
3. CLEAR AIR TURBULENCE (CAT)	OPERATIONAL	20				BELT SANDER TEST, CHECKED OPTICAL ALIGNMENT
4. FIR INFRARED SKY EMISSION (FIR)	OPERATIONAL	1				TURN ON ELECTRONICS AND CHECK FOR SIGNAL
5. EBERT SPECTROMETER (FOR ERTS UNDER [illegible]HTS)	OPERATIONAL	1/4				THIS EXPERIMENTER DID NOT HAVE TIME FOR MORE THAN MINIMAL OPERATIONAL CHECKS
6. INFRARED RADIOMETERS	CALIBRATION	1/2				USE PORTABLE RADIOMETER CONE TO CALIBRATE BEFORE AND AFTER MISSION
7. AL_2O_3 HYGROMETER	OPERATIONAL	1				MEASURE AMBIENT HUMIDITY ON GROUND

Experiment Reliability and Operational Problems

Table C-5 summarizes the performance of experiments on the August 1972 Mission in terms of the overall data-collection effort.

The only generalization that can be made concerning reliability is that experiments containing the most experimenter-built equipment had the fewest problems per flight. However, even this statement is based on subjective, and possibly incomplete, data. Individual experimental problems are outlined below and in table C-6.

Stratospheric Air Sampling (SAS)

This experiment was flown twice in the Ocean Color Expedition under the name of gas sampling and analyzing system. The first objective was to measure atmospheric trace gases; the second was to evaluate commercially available system components. On the last two flights, the SAS experiment was augmented by preliminary tests of equipment to collect aerosol particles from the stratosphere.

Two of the problems that arose during flight were: (1) the measured carbon-dioxide concentration fluctuated periodically in a manner that indicated malfunctioning operation, and (2) the compressor pump overheated. The second problem was minimized by placing dry ice on the pump.

Atmospheric Sampling Program (ASP)

This experiment, also from the Ocean Color Expedition, was modified with a new rack of equipment. From the very first flight, the NO_x, O_3, and CO_2 monitors were plagued with problems of low sensitivity, poor regulation, and unstable tuning, respectively. While no one problem was serious enough to severely impede operation, their cumulative effect was one of nagging irritation.

Clear Air Turbulence (CAT)

This experiment had not been flown before the August 1972 Mission, and this mission provided the first opportunity to check out the operation of the system. The experiment operated well on the first flight, but no signal was obtained owing to the lack of particulate matter at the altitude flown.

On one flight, a suspected problem finally surfaced. When the aircraft dived, the pressure increase in the laser cavity caused the laser output frequency to change. No data were lost, but the next series of flights will include an automatic frequency control as part of the equipment.

Far-infrared Sky Emission (FIR)

This experiment had been improved since the last time it was flown. On the first flight, thermal noise developed on one detector as a result of a damaged Dewar, which was replaced in flight with a spare and later repaired. On later flights, noise developed in the experimenter's tape recorder.

TABLE C 5. PERFORMANCE OF EXPERIMENTS IN FLIGHT

EXPERIMENT	FLIGHT 1	2	3	4	5	6	7	8	9
SAS	A		A				C	C	C
ASP	F	C	B	A	B	B	E	A	C
CAT	A	C		B	B	B	B	A	B
FIR	B		B			B	B	B	B
EBERT SPECTROMETER	—	—	—	--	--	B			
INFRARED RADIOMETERS	B					B	B	B	B
AL_2O_3 [illegible]ROMETER	D	D	D						

A = NO PROBLEMS
B = MINOR PROBLEMS NO DATA LOSS
C = MINOR PROBLEMS SLIGHT DATA LOSS
D = MAJOR PROBLEMS NO DATA LOSS
E = MAJOR PROBLEMS SIGNIFICANT DATA LOSS
F = COMPLETE FAILURE IN FLIGHT
— = EQUIPMENT NOT ON AIRCRAFT
-- = EXPERIMENTERS DID NOT FLY

TABLE C-6. PRE-MISSION CHECKOUT AND DATA FLIGHT PROBLEMS

EXPERIMENT	PROBLEM DESCRIPTION	IMPACT ON DATA: NONE	IMPACT ON DATA: LIMITED	IMPACT ON DATA: SEVERE	REPAIR REQUIRED: GROUND	REPAIR REQUIRED: FLIGHT
1. STRATOSPHERIC AIR SAMPLING (SAS)	CO_2 MONITOR MALFUNCTION			X	X	
	VACUUM PUMP OVERHEATED		X			X
	LEAK IN PLUMBING LINE		X			X
	PROBE DID NOT RETRACT		X		X	
2. ATMOSPHERIC SAMPLING PROGRAM (ASP)	SO_2 MONITOR WAS INOPERATIVE			X	X	
	NO_x MONITOR LOST SENSITIVITY		X		X	
	CO MONITOR HAD LOW SENSITIVITY		X		X	
	O_3 MONITOR HAD POOR REGULATION		X		X	
	O_3 MONITOR HAD SOME SLIGHT REGULATIONS PROBLEMS		X		X	
	CO_2 MONITOR HAD UNSTABLE TUNING		X		X	
	NO_x MONITOR HAD LOW SENSITIVITY		X		X	
	STRIP CHART RECORDER MALFUNCTIONED FOR SHORT TIME		X		X	
	O_3 ANALYZER PLUMBING HAD VALVE AND FLOW REGULATION PROBLEMS	X			X	
	CO_2 ANALYZER OSCILLATOR DRIFTING	X			X	
	NO_x STRIP CHART RECORDER RAN OUT OF INK		X			X
	VACUUM PUMP WORKED INTERMITTENTLY		X		X	
	CO_2 DETECTOR OPERATED AT HIGH NOISE LEVEL AT TIMES		X		X	
3. CLEAR AIR TURBULENCE (CAT)	TAPE RECORDER DRIVE STOPPED		X			X
	CIRCUIT BREAKER TRIPPED, ARCING IN EQUIPMENT	X				X
	PRESSURE INCREASE DURING DIVE CHANGED LASER FREQUENCY		X		X	
	TAPE RECORDER JAMMED	X				X
	LASER POWER OUTPUT LOWER THAN EXPECTED		X		NO FIX MADE DURING MISSION	
	TAPE RECORDER NOISY	X				X
4. FAR INFRARED SKY EMISSION (FIR)	NOISE IN PLAYBACK PART OF TAPE RECORDER		X		X	
	NOISE IN DATA FROM DAMAGED DEWAR		X		REPLACED WITH SPARE	
5. EBERT SPECTROMETER (FOR ERTS UNDERFLIGHTS)	TAPE RECORDER MALFUNCTION GARBLES DATA RECORD		X		X	
6. INFRARED RADIOMETERS	IMPEDANCE MISMATCH OF STRIP CHART AND AMPLIFIER		X		X	
7. AL_2O_3 HYGROMETER	SENSOR OPEN CIRCUITED		X		X	
	SENSOR OPEN CIRCUITED		X		X	
	SENSOR INTERMITTENT		X		X	

This noise was diagnosed as being in the playback part of the tape recorder and could not affect the quality of the recorded data.

Ebert Spectrometer (for ERTS underflights)

Equipment for this experiment had previously been flown on the Ocean Color Expedition. The upward-looking Ebert spectrometer was supplied by the experimenter, and two downward-looking cameras were supplied by Ames and operated by Ames personnel. The spectrometer was modified for the August 1972 Mission to provide data at selected wave lengths in contrast to previous measurements obtained over a continuous wave band.

Other than minor operational problems, there were apparently no malfunctions of this equipment during flight. However, postflight data evaluation showed a garbled data record on the magnetic tape recorder. Nevertheless, no serious loss of data occurred because good data were obtained on the strip-chart recorder.

Zenith and Horizontal Radiometers

The zenith radiometer had been flown on previous missions. For this mission, the experiment was modified with a new horizontal radiometer to permit measurement of infrared radiation at 15μ. This experiment provided support data to other experimenters on temperature and quantity of water vapor in the environment above the aircraft.

Al_2O_3 Hygrometer

This same basic instrument also was flown on the Ocean Color Expedition. For this mission, an additional sensor, modified to maximize air flowing by it, was incorporated into the experiment. The goal was to evaluate hygrometer sensors for the Department of Transporation's Climatic Impact Assessment Program.

On the first two flights, the new sensor developed an open circuit because of shape distortion resulting from air-stream pressures, and was replaced following the second flight.

On the third flight, the new sensor system performed only intermittently as a result of water vapor saturation from leaking cabin air. The experimenter elected not to fly for the remainder of the mission; the old sensor system was left to support the other experiments and seemed to work satisfactorily when operated by Ames personnel.

Data Handling

All experiments had a quick-look capability in addition to obtaining a permanent data record. Six used strip charts for this purpose, and the seventh used the data-display capability of the monitor TV system. Four used the ADDAS system for a permanent record, and three used magnetic tape recorders.

The experimenters arranged with the ADDAS operator at the beginning of a flight for an ADDAS printout of aircraft flight parameters in addition to those from their experiments. On most flights, the data-printout rate varied from rates as rapid as once per second to record rapidly changing events, such as passage through the tropopause or an aircraft wake, to once every 10 to 30 seconds when things were quiet.

Safety

The Airworthiness and Flight Safety Review Board met August 4, 1972, to review the safety aspects of experiments to be flown on the CV-990. The points discussed included procedures for transferring liquid helium in flight, structural properties of a fairing and gas-sample collecting mechanism, use of ethylene gas in an ozone-detection system, and strength testing of a special polyethylene window. Guidelines were discussed for categorizing the CV-990 as a commercial aircraft providing program support or, by virtue of its modifications to accommodate airborne experiments, as a research airplane. A short safety briefing on emergency procedures was held aboard the CV-990 for all participants who had not flown in the past year.

Safety requirements are listed in the Experimenters' Handbook. Any situations not specifically covered in the handbook were resolved in consultation with the mission manager and the Airworthiness Engineering Group. Their solution in turn was submitted to the Airworthiness and Flight Safety Review Board for review and approval. The flight safety of experiments was monitored at intervals during the design, construction, and installation of equipment. Aircraft inspectors examined the installed equipment to make sure it was safe, padding any sharp corners of racks, ensuring that all wires were taped out of the way, and looking for other potential hazards.

Documentation

An Experimenters' Bulletin was issued July 17, 1972, which announced the integrated flight plan for the August mission. It provided a schedule of events for the period of July 26 to September 7, information concerning flight lunches and coffee, and available insurance coverage for mission activities.

There also was considerable correspondence between the ASO program manager and the experimenters, including requests for flight time and discussions of funding, specific flight plans, and details of data recording and equipment installation. Experimenters with new equipment submitted descriptive drawings and stress analyses for approval prior to installation. The usual in-house work orders, flight requests, and the like were issued.

Appendix D

GIACOBINID METEOR SHOWER AND UPPER ATMOSPHERIC PHYSICS EXPEDITION

Mission Objectives and Planning

In November 1971, a meteor scientist at the Langley Research Center (LRC) of NASA initiated a proposal for airborne optical observations of the 1972 Giacobinid meteor shower. This meteor shower was of major scientific interest because of its probable high intensity, perhaps up to 10,000 meteors per hour; and the unique character of the meteoroids from this comet—their composition, light weight, and consequently, their deceleration at higher altitudes and relatively lower velocities during the visible period. However, the shower was predicted to occur at a time when daylight would exist throughout North America and most of Europe, precluding optical ground observations in these areas. Observations from an airborne platform were an attractive alternative.

During the initial investigation of the scientific merits of the proposed expedition, the Physics and Astronomy Directorate, NASA Headquarters, suggested that other experiments with different objectives be included in the payload because of the uncertainty of the intensity of the meteor shower. As a result, mission planning provided for airborne observations of auroras and outer atmospheric and magnetospheric conditions, by means of chemical releases from sounding rockets. The feasibility of using the CV-990 aircraft for the proposed observations was evaluated by the program manager for Geophysics and Space Sciences of the Airborne Science Office (ASO) at Ames.

Three potential observing regions were identified—the Ural Mountains in Russia, Saudi Arabia and Iran, and the Northwest Pacific Ocean beyond the outer Aleutian Islands. The last of these, with Alaska as the base of operations offered the best opportunities for conducting all the airborne observations and for obtaining the most overall scientific return at the lowest operational costs.

In January 1972, the ASO program manager submitted to the Headquarters program office and to the Airborne Research Steering Committee (ARSC) a preliminary plan and recommendation for a Giacobinid Meteor Shower Expedition. The ARSC gave tentative approval of the mission with its several research objectives. In mid-February the Headquarters office requested a firm plan for a two-week Alaskan mission. The ASO manager responded in March with the mission outline, schedule, costs, and a list of potential experimenters. After further negotiations with Headquarters and the principal investigators, a definitive mission proposal was submitted on May 8, and approved by the program office and ARSC on May 12. At this time the ASO program manager was assigned complete responsibility as the mission manager.

The data-gathering flights began only 4-1/2 months after final mission approval on May 12, 1972, an exceptionally short interval for a program of this magnitude and complexity. The establishment of a close working relationship between the Airborne Science Office and the Headquarters Program Office beginning with the first preliminary mission recommendation was an important factor in cutting the lead time to a minimum. In addition, however, the ASO manager and the rest of the management team had started arrangements for the expedition on a conditional

basis well before the final approval came. It was planned that the airplane would stay during the first week of October at Cold Bay on the tip of the Alaska Peninsula and stop for refueling, if necessary, at Shemya AFB in the outermost Aleutian group. The second week of October would be scheduled for the aurora and chemical-release observations with the airplane based at Eielson AFB in Fairbanks, Alaska. This base, well-known from previous expeditions, is within the auroral oval and also close (50 miles) to the rocket-launch facility at Poker Flat. In early April, the Resident Supervisor of the contract group responsible for the CV-990 and logistics support visited Cold Bay to inspect its facilities, and to discuss informally the availability of Shemya AFB with the Alaskan Air Command Headquarters in Anchorage. He advised that the expedition could operate at Cold Bay and probably refuel at Shemya, and that Flying Tiger Line, which has a base at Cold Bay, would provide all the required ground-support equipment as well as meals and lodging for the expedition personnel. These arrangements were approved by the CV-990 Command Pilot, Ames Flight Operations Branch. Meanwhile, the ASO program manager completed arrangements with the USAF for support at their Alaskan bases, particularly for staying at Eielson AFB for one week and possible refueling at Shemya AFB on three flights.

In early May, the ASO manager distributed a memorandum concerning the prospective mission to Ames support groups, including the Metals Fabrication Branch, which installs the experimenters' equipment in the aircraft, and the Flight Operations Branch, which provides the flight crew. This memo also was distributed to members of the Airborne Science Office, the Airborne Research Steering Committee, and to 42 other Ames and contractor personnel. After the official approval was given, the ASO manager verbally so advised the half dozen or so persons who would be most closely associated with the project.

Selection of Experiments

The unsolicited NASA/LRC proposal of November 1971 was the first proposal submitted for the Meteor Shower Expedition. Since the program was funded by Headquarters rather than by NASA/LRC, the originating center, the expedition had to be open to all interested and qualified scientists. The number of known meteor shower investigators in the United States and Canada was small enough, however, that they could be notified informally rather than by the usual Announcement of Flight Opportunity (AFO). In December 1971 and January 1972, the ASO program manager contacted by telephone a few of the active meteor scientists to obtain their opinion on the need for a Giacobinid Meteor Shower Airborne Expedition. During these conversations, the scientists were invited to submit proposals and to inform their colleagues of the proposed expedition. The Headquarters program office similarly informed potential experimenters. As a result, three more proposals were received in January; a formal proposal from a team from Marshall Space Flight Center of NASA; a simple letter of intent from a team from the National Research Council of Canada; and a still simpler oral expression of intent by a team from the Dudley Observatory in Albany, New York. All these proposals were accepted. Two more expressions of interest, one from NASA-Manned Spacecraft Center and the other from a joint team from Centre National de Recherche Scientifique in France and Kitt Peak National Observatory in Arizona, were later withdrawn.

Potential experimenters in other disciplines were also informally advised of the impending expedition. For some years, the Headquarters program office has sponsored the study of thermospheric winds by means of chemical releases from Nike-Apache sounding rockets. The principal investigator in that study had already used the CV-990 as the primary observation post for two chemical releases at Wallops Island in September 1971. The airborne expedition to Alaska would give him an opportunity to study thermospheric winds in the arctic region and to confirm the techniques of photographing daytime chemical-release trails from aircraft altitudes, utilizing sounding rockets fired from the range at Poker Flat (operated by the University of Alaska).

Several experimenters from an earlier CV-990 auroral expedition were informed of the tentative mission by the ASO program manager. Most of the auroral scientists were not interested because of the relatively short duration of the field try and the need for sharing observational time with other scientific objectives. One, however, organized a joint aircraft-satellite auroral observation experiment. Through contacts with experimenters using other research vehicles, he learned that the ISIS-II satellite would be in the local noon-midnight polar orbit in early October and that the USAF/AFCRL KC-135 airborne observatory would then be studying daytime auroras in the local noon area over the Greenland Sea. In June 1972, this scientist submitted a preliminary proposal for two or three underflights of the ISIS-II satellite at Alaskan midnight in coordination with the KC-135 aircraft in the noon sector. Later, he arranged to obtain data from a USAF Vela satellite in the magnetospheric tail. The coordinated measurements would give a comprehensive, simultaneous picture of the causative particle precipitation patterns observed by the satellites and the resulting optical auroras observed by the aircraft.

This principal investigator proposed to install and operate two all-sky cameras on the CV-990. To complete his studies, photometric data on the auroral intensities were needed. A colleague, who was an experienced CV-990 experimenter, offered to collaborate in the experiment, and an amended proposal that included the photometric measurements was submitted and approved in September.

A senior scientist from another Government agency, a frequent investigator on CV-990 flights, was orally invited to participate. The prospective flight routes would allow him to measure atmospheric water vapor in geographical areas that had not been systematically studied. As usual, his data on the state of the atmosphere would benefit the other CV-990 experimenters making optical observations. A formal proposal was submitted in July and accepted in August.

In early August, Headquarters suggested that an Ames research team could conduct an experiment to collect dust or particles from the meteor shower that might drift down to aircraft altitudes. They readily agreed to participate since their collectors were in use on the August 1972 mission and could remain on board. Subsequently, two of their four aerosol collector units on the CV-990 were allocated to an experimental group at the University of Washington.

The funding of the experimenters was handled jointly by the Headquarters program office and the Airborne Science Office. The three U.S. meteor experimenter teams were already funded by Headquarters. The Canadian meteor experimenters were funded by their own facility, the National Research Council of Canada. Headquarters also handled the funding for the chemical releases, since it had been supporting the experiment for many years. The funds for the aurora and the atmospheric water-vapor experiments were transferred to ASO from the Headquarters

program office as part of the total funds for the expedition. The Ames aerosol experiment did not require any funding since the apparatus and the aircraft mount were on hand and the experimenters did not accompany the expedition.

The Role of the Experimenter

An experimenter normally is responsible for the preparation of brackets and supports for mounting his apparatus in the aircraft. Because of the extensive fabrication required and the short time available, however, the ASO program/mission manager decided that Ames would handle the design and the fabrication of all new mounting hardware for this expedition. Three experiments had flown previously in the CV-990 and could use existing mounts, leaving 13 experiments for which mounting hardware was required.

The experimenters were still responsible for preparing their experimental equipment, obtaining the components, and checking them out. They had to assist in the installation of their experiments and operated their own experimental equipment during the flights. The one exception was the aerosol collector experiment; inflight operation of this experiment was merely an off-on function, and maintenance involved only a simple, quick change of collector elements between flights. Therefore, the CV-990 facilities manager, with the mission manager's concurrence, agreed to be responsible for the experiment during the expedition. Only rarely have ASO personnel consented to operate and maintain an experiment for an absentee experimenter; in this case, the key factors were the simplicity of the operation and the manager's familiarity with the equipment from previous flights.

The experimenters were responsible for reducing and analyzing their data. They were encouraged to keep the mission manager informed of the results of their data analysis.

Interactions between the Experimenters and the Mission Manager

Once the expedition was officially approved in mid-May, the interactions between the ASO mission manager and the experimenters entered a new phase. It was possible to omit the experimenters' meeting usually held at this time, because the ASO manager had already established (by telephone) effective relationships with the experimenters and had been discussing with them plans for the expedition; also, the relatively few meteor experimenters were in frequent contact with each other.

Communications between the mission manager and the experimenters, still mostly by telephone, now concerned principally the experiments to be mounted in the aircraft and the developing plans for the flights. In May and June, the experimenters sent the mission manager descriptions of their experiments, sketches of the desired arrangement of their equipment, requests for optical window materials, estimates of electrical power requirements, and the like. This information was used to prepare a floor plan, or arrangement, of the experiments in the airplane. Telephone calls and

backup correspondence as necessary to transmit detailed data remained the means of communications through midsummer. When enough general information of interest to experimenters and support personnel had accumulated, Experimenters' Bulletins were issued by the ASO manager, the first one in early August and the second one in early September, which contained the latest schedule, floor plan, list of experimenters, arrangements for field bases, flight plans, etc.

With two exceptions, the ASO manager had no personal contact with any of the experimenters until they arrived at Ames in September for the installation of their equipment in the aircraft.

Some of the meteor experimenters met on two occasions. In July, three of the four meteor teams attended the Gordon Conference in New England; and in August, another group of three teams made joint observations of the Perseid meteor shower from the NRC Meteor Observatory at Spring Hill, Ontario, Canada. The cognizant manager from the Headquarters program office attended the Gordon Conference and conducted an informal meeting about the expedition with the airborne experimenters. The August gathering at Spring Hill was attended by one of the ASSESS contractor observers. These two meetings, which illustrate the close association of the meteor shower community, gave the airborne experimenters opportunity to exchange information on their individual plans and objectives for the Giacobinid airborne expedition.

In mid- and late summer, when the experimenters were actively involved in preparing their experiments, they began to discuss their requirements and problems directly with other members of the ASO management team—namely, with the ASO support-contract designer who was designing the mounting brackets for most of the experimenters, the assistant mission manager, and the programmer for the ADDAS. Interactions between the management staff and the experimenters rapidly reached a personal basis with the start of the installation period in early September, and by mid-September each experimental team had at least one responsible member at Ames who was busy with his onboard installation.

The compactness of the ASO facility provided ready access to the mission management and support staff for any experimenter requiring assistance. The ASO shop where the experimenters assembled and checked their equipment was about 30 meters from the aft end of the CV-990 parked in the Ames hangar. The ASO laboratory technician was available full time, and the assistant mission manager and the aircraft facilities manager spent most of their time in the shop or the airplane during the installation period. The mission manager went through the airplane and the shop at least twice a day to check on the status of the installation and to discuss informally with the experimenters the current developments in their own experiment as well as in the expedition as a whole. Depending on the level and extent of support needed, any of these four ASO men could call on other groups and resources at Ames for assistance.

One formal experimenters' meeting was held on September 26 to discuss the practice and checkout flight for the evening of September 28, logistics arrangements (housing, meals, support facilities, etc.) in Alaska, and possible observation of the University of Alaska—AEC/LASL barium release on the ferry flight to Cold Bay.

At Cold Bay, experimenters' meetings were held well before each flight, attended by the experimenters, the management and support staff, the flight crew, and the supervisor of the ground crew. In addition to the usual discussion of the preceding flight and particular items or

conditions desired by individual experimenters for the next flight, there were detailed discussions of topics particularly pertinent to the Giacobinid meteor shower. The techniques for the measurement of the meteor rate both on the practice and the shower flights were also worked out. At the meeting of October 5, the senior Canadian scientist gave an interesting and authoritative description of the very intense 1946 Giacobinid shower, which he had observed and which we hoped would be duplicated on October 8.

As a result of these "formal" experimenters' meetings, meteor experimental teams arranged a procedure for collaboration in making real-time judgments on the development of the meteor shower, even though each team retained its own independent objectives. The other members of the expedition, the nonmeteor experimenters, the flight crew, the management, and the support staff all gained a good understanding and a genuine appreciation of the meteor scientists' objectives and methods. In the second week of the expedition, which operated toward nonmeteor objectives, the meteor scientists responded enthusiastically with their instrumentation to support the other experiments.

Many other factors helped this growth of cooperation and team work, including the compactness of the two field bases and their isolation from urban diversions, the "boarding-house" atmosphere of eating and living together, and the use of a common channel on the aircraft intercom monitored by one member of each experimental team. This last factor kept the experimenters immediately aware of all developments during a flight and provided opportunity for free discussion of events during the observations.

After the expedition transferred to Eielson AFB for the auroral and the chemical-release observations in the second week, all personnel were required to be on a stand-by status for a possible flight every night except one. Flight schedule and other pertinent information were exchanged during chance meetings in the quarters where personnel were billeted, in the mess hall, on the street, at the airplane, etc. Details of a particular flight were communicated to the experimenters as they assembled on board the aircraft for the flight. When time permitted, the announcement of a flight was posted at the entries of the billeting quarters and the airplane. Although these means of communication seem at first to be loose and haphazard, they proved highly effective; by this time, all members of the expedition were well aware of the nature of the operation and of their roles in it, and took the responsibility of keeping themselves informed by frequent checks with the management staff.

The relationships between the mission manager and the two principal investigators responsible for airborne studies the second week were much more direct. The principal experimenter for the chemical releases met often with the mission manager and the flight planner/navigator to assess the weather conditions and to evaluate the prospects for rocket launches. The principal auroral investigator kept in touch with the mission manager by telephone from his office at the University of Alaska, 30 miles away, and the mission manager visited the university one afternoon when there was no flight scheduled that night.

After the mission was over, the ASO manager kept in touch with the experimenters and received both verbal and written preliminary reports on their results. Through these contacts, the exchange of information among the meteor scientists was monitored. Also, the transfer of the

video tapes taken by the meteor scientists on the auroral and the chemical release flights to the experimenters interested in those phenomena was handled by the ASO manager.

Experimental Equipment

Design and Construction

Of the 42 experiment sensors used during the Meteor Shower Expedition, 35 were off-the-shelf, custom-commercial film, or TV camera systems. About half of these were modified for spectroscopy by either the producing firm or by the experimenter. Some required only minor changes in optics so that the system would accept a diffraction grating. In one experiment, eight cameras were ganged together for operation by a single control; in another, the shutter and film advance system were completely altered by the experimenter.

The seven other experiment sensors used on this expedition, consisting of three photometers, three IR radiometers, and an aerosol collector, were of diverse design and construction. The birefringent-crystal photometer, the aerosol collector, and the IR radiometers were designed and constructed by the experimenters; the first two comprised primarily experimenter-built components, while the IR radiometers were constructed from off-the-shelf components, and had been flown on previous missions in a slightly different form. The other two photometers were custom produced to specification by a commercial firm.

Table D-1 lists the types of hardware used in the experiments for the Meteor Shower Mission. The most evident feature is that the experiment components were largely off-the-shelf or custom-commercial products, presumably because most were camera or TV systems. As noted, many of these image-recording systems were equipped with diffraction gratings to produce meteor spectra.

Experiments 1 through 6 accounted for nearly 50 percent of the sensor units in the total experiment payload, and comprised predominantly custom-commercial hardware, built to the specific requirements of ground-based meteor observations. For airborne use, nine of these camera units were equipped with shutter-trigger systems fabricated by the experimenter. Most other experiments on this expedition used predominantly off-the-shelf equipment.

In general most of the experiments in the meteor shower payload were considered to consist of well developed equipment. That is, either they were produced by specialized commercial firms, had been used repeatedly for scientific observations (e.g., the IR radiometers and birefringent crystal photometer), or were so simple in design as to be inherently well developed (e.g., the aerosol collector).

Testing

Experiment testing and checkout for the meteor shower payload did not follow the usual ASO pattern, which includes home laboratory tests by the experimenter to ensure that the

TABLE D-1. EXPERIMENT CHARACTERISTICS

EXPERIMENT	COMPONENT	CONSTRUCTION: OFF THE SHELF	CUSTOM COMMERCIAL	MODIFIED COMMERCIAL	EXPERIMENTER BUILT	DIMENSIONS (cm)	POWER DEMAND (WATTS)	COST ($)	WEIGHT (kg)
1-6. METEOR SPECTROSCOPY AND PHOTOGRAPHY OF CHEMICAL RELEASE EXPERIMENTS	70 mm CAMERA SPECTOGRAPH, f/1 (4)		X			25X46X56		50000 (EA)	34 (EA)
	MAKSUTOV CAMERA SPECTOGRAPH (6)		X			33 DIA X 72 LONG		2000 (EA)	9.1 (EA)
	SCHMIDT CAMERA SPECTOGRAPH (3)		X			20 DIA X 51 LONG		1600 (EA)	4.1 (EA)
	IR CAMERA SPECTOGRAPH (2)		X			15X15X15		2000 (EA)	4.5 (EA)
	IR PHOTOMETER (2)		X					400 (EA)	1.8 (EA)
	IMAGE INTENSIFIER CAMERA		X			46X51X160	500	100000	160
	GRATING FOR II CAMERA		X						4.5
	SHUTTER TRIGGER (9)				X	5 DIA X 38 LONG			0.9 (EA)
	TRIGGER POWER SUPPLY		X				200		25
	CAMERA CONTROL UNITS		X				300		131
	K-24 CAMERA	X							23
7 and 8. METEOR SPECTROSCOPY	F-24 CAMERAS (4), WITH GRATINGS	X					0	50 (EA)	23
	UV LENS FOR F-24 CAMERA		X					3000	
	VINTEN CAMERA (WITH JUMP FILM SYSTEM)			X			100	2000*	
9 and 10. METEOR SPECTROSCOPY AND PHOTOMETRY; CHEMICAL RELEASE PHOTOGRAPHY	SEC VIDICON CAMERAS (2)	X				1[illegible]X61X13	400	2000 (EA)	18 (EA)
	CAMERA CONTROL (2)	X				48X23X18		22000 (EA)	13 (EA)
	SYNC. GENERATOR (2)	X				48X51X5		2000*	3.6 (EA)
	MONITOR (2), TV	X				23X41X25		2000*	14 (EA)
	VIDEO RECORDER (2)		X			76X46X38	180	10000 (EA)	43 (EA)
	GRATING (2)	X				28 DIA X 2.5			2.2 (EA)
11. METEOR SPECTROSCOPY	IMAGE ORTHICON SYSTEM	X				69X25X25	200		29
	POWER SUPPLY	X				25X13X20			7.2
	MONITOR	X				46X23X28	130		19
	OSCILLOSCOPE	X				48X20X33	425		16
	VIDEO RECORDER (2)	X				76X51X33	350 (EA)		45 (EA)
	ISOLATION TRANSFORMER	X				18X10X10			5.0
	GRATING		X						
12. CHEMICAL RELEASE PHOTOGRAPHY	CAMERAS f/2.8, 70 mm (8)	X							
	FILTERS (10 Å WIDE BAND PASS)		X			20X25			
13 and 14. OBSERVATION OF AURORAS; PHOTOGRAPHIC AND PHOTOMETRIC	ALL SKY CAMERAS (2)		X			25X31			
	PHOTOMETER, BIREFRINGENT CRYSTAL				X	76X76X137	500		
	RECORDER, STRIP CHART (GFE)								
15. IR ZENITH AND NADIR RADIOMETERS	DIGITAL VOLTMETER	X				14X10			
	CONTROL PANEL				X	9X13	170	17,000 (TOTAL)	90* (TOTAL)
	THERMOMETER	X				23X18			
	FAIRING & PORT		X						
	SENSOR UNITS (3)	X				30X30X30			
16. AEROSOL COLLECTOR	COLLECTOR-ARM FAIRING				X				14
	COLLECTOR-ARM ACTUATOR				X				
	COLLECTOR WIRES				X				

*ESTIMATED

experiment is operational and meets desired requirements. Most of the experiments to be flown in the planned mission had been in use for years at ground-based observatories or had been on previous CV-990 missions and hence their operational capability and readiness for the expedition was assured.

The aerosol collector experiment was unique in its simplicity of construction, which obviated any need for home-base testing. This experiment consists of an arm that is extended into the airstream and then is retracted into a sealed container. A wire at the end of the arm collects particles from the airstream. The experiment is readied for flight by cleaning and sealing the collector wire in a clean-room facility and attaching it to the arm. The extension and retraction of the arm is then the only operational feature requiring checkout.

All experiments were tested in some fashion after arrival at Ames (table D-2). These tests involved primarily the focusing of TV and film camera systems, some of which were accomplished in an optical dark room prior to installation. After all experiments were in place, the aircraft was positioned for daytime focusing on distant objects and for star focusing at night. The usual checks were made for interferences with aircraft power systems and between experiments. In addition, the IR radiometers were recalibrated and the crystal photometer experiment was operated and calibrated with an Ames strip-chart recorder furnished for use during the mission.

Installation and Interface Requirements

Matching of the many ground-based experiments to the optical, structural, and electrical interfaces of the aircraft was accomplished with remarkable ease, in view of the short time allocated for the physical installation and the large numbers of brackets and supports required. Thirteen of the 16 experiments required fabrication of mounting hardware; 3 had been flown previously on the CV-990 and existing hardware could be used with little modification. Table D-3 summarizes data on experiment installation activity and support requirements.

The power demand of the meteor shower experiment payload was unusually small. Experimenter's equipment drew less than 4000 W of 60-Hz power—well under 25 percent of that available. The amount of 400-Hz power used was negligible.

Experimenters made use of both zenith ports, and 21 of the 22 ports and windows (65° and 14° elevation) that could accommodate optical glass. In addition, several of the standard passenger windows were used by experimenters who did not require optical quality glass. In all, 27 windows were tested for strength and optical properties prior to the mission.

Table D-4 summarizes experimenter use of the ADDAS and other support equipment. Only the chemical-release photography experiment and the IR radiometers utilized the ADDAS computer to handle data. In the case of the chemical-release experiment (12), camera shutter pulses were recorded against time, whereas the radiometers provided raw data to the ADDAS system for conversion into quantity of atmospheric water vapor above the aircraft.

A time-code generator was available, and although none of the experimenters incorporated these signals directly into his record, an accurate visual display of time was provided to all, and the

TABLE D 2. EXPERIMENT PREFLIGHT TESTING AT AMES

NO.	EXPERIMENT	TYPE OF TEST	TEST EFFORT: TIME TESTED, (MAN-DAYS)	TEST EFFORT: AMES SUPPORT*	TEST EQUIPMENT FURNISHED
1 6	METEOR SPECTROSCOPY AND PHOTOGRAPHY OF CHEMICAL RELEASE EXPERIMENTS	ALIGN AND FOCUS	9	DEVELOP FILM	OPTICAL TARGET, OPTICAL DARK ROOM
7 & 8	METEOR SPECTROSCOPY	FOCUS, OPERATION	1	DEVELOP FILM, REPAIR LENS HOLDER IN INSTRUMENT SHOP	NONE
9 & 10	METEOR SPECTROSCOPY AND PHOTOMETRY; CHEMICAL RELEASE PHOTOGRAPHY	FOCUS, OPERATION	2	NONE	NONE
11	METEOR SPECTROSCOPY	FOCUS, OPERATION	2	NONE	NONE
12	CHEMICAL RELEASE PHOTOGRAPHY	CHECK TIMING	1	DEVELOP FILM	NONE
13 & 14	OBSERVATIONS OF AURORAS	FOCUS, SYSTEM INTEGRATION	2	DEVELOP FILM	STRIP CHART RECORDER
15.	IR ZENITH AND NADIR RADIOMETERS	CALIBRATE	1/2	NONE	LIQUID NITROGEN
16	AEROSOL COLLECTOR	OPERATION	1/4	NONE	NONE

*CV 990 POSITIONED AT END OF RUNWAY FOR STAR FOCUSING, EXPERIMENTS 1-14

TABLE D-3 EXPERIMENT INSTALLATION AND SUPPORT REQUIREMENTS

NO.	EXPERIMENT	INSTALLATION PROBLEM	MOUNTING HARDWARE		REQUIRED ASO/AMES SUPPORT	
			AVAILABLE	FABRICATED	PERSONNEL	EQUIPMENT OR FACILITY
1 – 6	METEOR SPECTROSCOPY AND PHOTOGRAPHY OF CHEMICAL RELEASE EXPERIMENTS	MINOR ALIGNMENT PROBLEMS		X	AIRCRAFT DESIGNER SHEET METAL TECH. ELECTRONICS TECH.	FORK LIFT METAL SHOP FACILITIES
7 & 8	METEOR SPECTROSCOPY	MINOR ALIGNMENT PROBLEMS		X	AIRCRAFT DESIGNER SHEET METAL TECH. ELECTRONICS TECH.	FORK LIFT METAL SHOP FACILITIES
9 & 10	METEOR SPECTROSCOPY AND PHOTOMETRY; CHEMICAL RELEASE PHOTOGRAPHY	NONE	X	X	SHEET METAL TECH. ELECTRONICS TECH.	FORK LIFT METAL SHOP FACILITIES
11	METEOR SPECTROSCOPY	NONE		X	SHEET METAL TECH. ELECTRONICS TECH.	FORK LIFT METAL SHOP FACILITIES
12.	CHEMICAL RELEASE PHOTOGRAPHY	NONE		X	SHEET METAL TECH. ELECTRONICS TECH.	NONE
13 & 14	OBSERVATIONS OF AURORAS	NONE	X	X	SHEET METAL TECH. ELECTRONICS TECH.	FORK LIFT METAL SHOP FACILITIES
15	FIR ZENITH RADIOMETERS	NONE	X		SHEET METAL TECH. ELECTRONICS TECH.	NONE
16	AEROSOL COLLECTOR	NONE	X		SHEET METAL TECH. ELECTRONICS TECH.	NONE

TABLE D-4. SUPPORT EQUIPMENT UTILIZATION

NO.	EXPERIMENT	AMES SUPPORT PROVIDED	EQUIPMENT USED*	
			GROUND	FLIGHT
1–6.	METEOR SPECTROSCOPY AND PHOTOGRAPHY OF CHEMICAL RELEASE EXPERIMENTS	DARK ROOM FACILITIES	DEVELOP FILM	LOAD FILM
7 & 8	METEOR SPECTROSCOPY	DARK ROOM FACILITIES	DEVELOP FILM	VOICE COUNT RECORDED
9 & 10	METEOR SPECTROSCOPY AND PHOTOMETRY; CHEMICAL RELEASE PHOTOGRAPHY	NONE		
11.	METEOR SPECTROSCOPY	NONE		VOICE COUNT RECORDED
12.	CHEMICAL RELEASE PHOTOGRAPHY	ADDAS, DARK ROOM FACILITIES	DEVELOP FILM	SHUTTER PULSES TO ADDAS FOR TIME CORRELATION
13 & 14.	OBSERVATIONS OF AURORAS	STRIP CHART RECORDER		RECORD CRYSTAL PHOTOMETER DATA
15.	IR ZENITH AND NADIR RADIOMETERS	ADDAS		DATA TO ADDAS FOR PROCESSING
16.	AEROSOL COLLECTOR	NONE		

*AVAILABLE TO ALL EXPERIMENTERS
- TIME CODE GENERATOR
- VOICE RECORDING
- VOICE TIME COUNTS
- NAVIGATIONAL DATA

navigational data recorded by the ADDAS were time coded for postmission use. A voice count was used to coordinate observations during meteor-shower and chemical-release events. This count was recorded on audio recorders by two of the experimenter teams.

Navigation parameters were provided to the experimenters on one channel of the closed-circuit TV monitors postioned within the passenger compartment. An image of the sky from one experimenter's TV camera was displayed on the alternate channel, which proved generally to be of greater interest to the other experimenters.

Utilization of spares was not a major consideration on this expedition. In one instance, a photomultiplier tube in a trigger-control circuit for a group of spectrographs was replaced; in another, several circuit cards were exchanged between two TV camera systems operated by the same experimenter.

Experiment Reliability

The meteor shower expedition experienced few inflight problems; most of them were minor (table D-5). In the present context, a problem was considered significant if at least 20 percent of the data was lost, or could have been lost had active data retrieval been attempted.

Problems given in table D-5 are categorized by origin: the aircraft, the aircraft utilities or support equipment, the flight environment, experimenter error, or experiment malfunction. The table also indicates the predominant type of hardware used in the experiment, experiment state of development and complexity (number of components), and experiment inflight experience.

This summary shows that less than half the problems were severe enough to affect the research data significantly. Only 11 significant malfunctions occurred among the 16 experiments (including 42 individual sensor systems) carried on the expedition. Over the total number of experiment flights (117 for this expedition), the average incidence of problems is about one in ten experiment flights.

In terms of problem origin, experimental equipment accounted for the majority (24 out of 33) of problems, followed in diminishing order by aircraft support equipment and experimenter error. One flight was terminated because of an engine problem; no environmental problems were experienced during the expedition.

The relatively high overall experiment reliability experienced on the Meteor Shower Expedition has been attributed to the following factors:

1. Predominant use of off-the-shelf and custom-commercial components, which are inherently reliable because of their advanced state of development.

2. Extensive use of these experiments in previous airborne research programs or in ground-based observatories.

TABLE D-5. INFLIGHT EXPERIMENT PERFORMANCE

NO.	EXPERIMENT IDENTIFICATION	PREDOMINATE EXPERIMENT CONSTRUCTION	EXPERIMENT DEVELOPMENT/ COMPLEXITY	EXPERIMENT DATA FLIGHTS	PROBLEM STATISTICS (ALL/SIGNIFICANT)				
					AIRCRAFT	AIRCRAFT UTILITIES	ENVIRON-MENT	EXPERI-MENTER ERROR	EXPERIMENT MALFUNC-TIONS
1 – 6	METEOR SPECTROSCOPY AND PHOTOGRAPHY OF CHEMICAL RELEASE EXPERIMENTS	CUSTOM-COMMERCIAL (ALL)	HIGH/MEDIUM (ALL)	45 (ALL)	ONE FLIGHT TERMINATED, ENGINE PROBLEM	0/0	0/0	1/1	5/4
7 & 8	METEOR SPECTROSCOPY	OFF-THE-SHELF (7) & MODIFIED-COMMERCIAL (8)	HIGH/LOW (BOTH)	8 (BOTH)		0/0	0/0	0/0	0/0
9 & 10	METEOR SPECTROSCOPY AND PHOTOMETRY; CHEMICAL RELEASE PHOTOGRAPHY	OFF-THE-SHELF (BOTH)	MEDIUM/HIGH (BOTH)	18 (BOTH)		1/0	0/0	1/1	5/5
11	METEOR SPECTROSCOPY	OFF-THE-SHELF	HIGH/HIGH	10		2/1	0/0	0/0	10/0
12	CHEMICAL RELEASE PHOTOGRAPHY	OFF-THE-SHELF	HIGH/LOW	6		2/1	0/0	0/0	2/0
13 & 14	OBSERVATION OF AURORAS	CUSTOM-COMMERCIAL (13), EXPERIMENTER-BUILT (14)	HIGH/LOW (BOTH)	10 (BOTH)	0/0	0/0	0/0	0/0	0/0
15	ZENITH & NADIR RADIOMETERS	OFF-THE-SHELF	HIGH/MEDIUM	10	0/0	1/1	0/0	0/0	0/0
16	AEROSOL COLLECTOR	EXPERIMENTER-BUILT	HIGH/LOW	10	0/0	0/0	0/0	0/0	2/2
			TOTALS	117	1/1	6/3	0/0	2/2	24/11

Safety

The primary safety considerations for the Meteor Shower Expedition were the mounting of the experimental equipment, the testing of the optical observation windows, and the survival equipment and techniques to be used for ocean and arctic flights. Previous missions had involved all these factors, and appropriate procedures were thus well established.

The certification of the experimental installations was facilitated by the use of the ASO standard racks and the use of experiments with prior CV-990 mission experience. A major factor in the area of safety, however, was the design and the fabrication of approximately 20 non-standard mounts at Ames. Preliminary concepts of these mounts were developed by the ASO contract-services designer, with contributions from the mission manager, and, more significantly, the engineer from the Airworthiness Group of the Flight Operations Branch. Once the preliminary designs had been evaluated by all three and approved verbally by the airworthiness engineer, the production drawings were made, approved by the airworthiness engineer, and delivered (within minutes) to the foreman of the Metals Fabrication Branch. In one case, an experimenter designed and built a new mount; he was not required to submit a stress analysis because the design was similar to one that had already flown on the CV-990.

The successive versions of the cabin floor plan, developed by the mission manager and the designer, were reviewed by the airworthiness engineer for such items as placement of life rafts; arctic survival kits; firefighting equipment; and obstruction of exits, aisles, seats, etc.

The safety of optical observation windows is a matter of great concern. Twenty-two optical windows plus five spares were prepared for this expedition. All the windows underwent environmental temperature and pressure tests, except one, which had been in bonded storage since previous testing. The windows were tested, as usual, in the Ames R & QA facility about 400 meters from the hangar, and installed under the supervision of the responsible R & QA engineer.

During the installation of the experimental equipment in the airplane (September 11 to 26), a certified aircraft inspector was on duty almost continuously on the CV-990 or in the ASO laboratory to check for such safety items as use of National Aerospace Standard (NAS) hardware at all load points, proper mechanical and electrical connections to the aircraft, emergency equipment (small fire extinguishers on the experimenters' racks), padding of sharp corners and "head knockers," nonflammability of materials (especially cloth), etc. Any discrepancies and omissions in each installation were noted, and following corrective action by the responsible experimenter or Ames technician (Metals Fabrication Branch), a final check was made and approval granted by the inspector.

The Airworthiness and Flight Safety Review Board (AFSRB) conducted its survey of the expedition in two parts. First, the board chairman, who is also the Chief, Flight Operations Branch, and his assistant branch chief reviewed the flight operations aspect of the mission, particularly the flight routes, arrangements for aircraft support at the field bases, plans for landing at alternate terminals, and the like, as presented by the command pilot, the navigator/flight planner, and the mission manager.

The next day, the full board held its operational engineering review, which concentrated on equipment installations in the aircraft. There was some discussion about the safety aspects of having equipment (e.g., cameras) mounted close to the optical windows, which are single panes of glass one inch thick. It was pointed out that all such windows have a safety cover in place while undergoing inflight thermal and pressure changes. The AFSRB approved of all expedition plans as presented.

Installation of a number of cameras in the field caused no problems from a safety standpoint, even though one unanticipated change occurred. This change involved the mounting of a small 35-mm camera at a regular passenger window. The airworthiness engineer at Ames suggested safe ways of mounting the camera in a telephone discussion with the expedition manager. When the mount was completed, the aircraft inspector on the expedition examined and approved it. Replacement of the meteor-shower spectrographs by chemical-release cameras at five windows at Cold Bay did not present any safety problems because a "dry run" on the changeover had been conducted and approved at Ames during the latter part of the installation period.

The experimenters' safety briefing was conducted on the day of the first flight by the safety-equipment technician from the Flight Operations Branch and by the CV-990 flight engineer. This briefing included the usual explanation of all safety and survival equipment on the aircraft. Because the severe arctic winter had not yet started, the experimenters' safety briefing did not include the USAF film on arctic winter survival, nor was the usual full outfit of USAF arctic clothing provided. The members of the expedition were issued only the parka, insulated cap, lined flight suit, heavy mittens, and duffle bag. (The parka and the cap were used by practically everyone for everyday wear around the field bases.) Safety briefings for those joining the expedition in the field, and for the occasional passenger, were conducted at boarding time usually by the mission manager and sometimes by the flight engineer.

Documentation

ASO-Experimenter Documentation

In the early planning stages, verbal communication, mostly by telephone and occasionally in person, was used extensively. Written correspondence was used only to transmit lengthy or detailed information such as the list and the sketches of each experimenter's components, desired orientation of the cameras, background information on the meteor shower, and so forth.

The two Experimenters' Bulletins that were issued came later in the program than is customary, mainly because the ASO program manager had already established excellent lines of communication with the relatively small number of experimenters while they were awaiting program approval by Headquarters. The Experimenters' Bulletin contained questionnaires requesting the following information from each principal investigator:

Bulletin No. 1

- Personnel in the experimenter's team
- Requirements for special materials and supplies (e.g., dry ice)

Time codes and pulse rates

Data-recording and processing requirements by the onboard computer system (ADDAS)

Preferred ferry flight schedule

Navigational data required in reduction of experimental data

Bulletin No. 2

Professional and home addresses and telephone numbers of each person to be on the expedition and of a person at home to be notified in case of emergency

Clothing sizes (for the arctic clothing)

No stress analyses were required from the experimenters.

The two Canadian participants had to supply special documentation in order to comply with the NASA and the Ames regulations on visits of foreign nationals. Their agency, the National Research Council of Canada, had to submit a formal identification and authorization for the two well-known scientists to participate in the expedition and to visit Ames. In practice, the formal NASA request was for a certification of the security classification of the two scientists, although the expedition itself was open and unclassified.

Internal Documentation

Table D-6 lists the internal documentation at Ames for the preparation and operation of the mission; frequency of use is also indicated. The use of these documents is outlined below.

Aircraft work order — Two of the eight aircraft work orders were major ones: one requested the ASO contract service group to provide all the design engineering support necessary for installing the experiments, and the other requested the Ames Metals Fabrication Branch to fabricate the mounting fixtures and to install all experimental equipment in the aircraft. The remaining six AWOs concerned specific items, such as the installation of the exterior hatches over the 65° observation window and the replacement of scratched passenger windows. It is significant that the first two AWOs covered practically all the work needed to install the experimental equipment in the aircraft.

Service request — Two of the 11 SRs covered major support services from other branches at Ames. One SR to the Metals Fabrication Branch was essentially a duplicate of the AWO to the same branch. The SR outlined estimates of the labor, time, and costs of the service requested and was the means of satisfying branch management that the requesting office had sufficient funds to cover the work. The corresponding AWO was routed so that all directly concerned with the safety and integrity of the aircraft were aware of the work to be done on the aircraft by various branches.

The second major SR, issued to the Photographic Technology Branch, requested the assignment of a photographer to accompany the mission, documentary photography of the expedition, and availability of film processing.

TABLE D-6. AMES INTERNAL DOCUMENTATION FOR THE METEOR SHOWER EXPEDITION

TITLE OF FORM	NUMBER USED
1. AIRCRAFT WORK ORDER (ARC 88)	8
2. SERVICE REQUEST (ARC 73)	11
3. PURCHASE REQUEST (ARC 31)	8
4. LOGISTICS SUPPORT CORRESPONDENCE	3
5. AIRCRAFT FLIGHT REQUEST (ARC 247)	2
6. FLIGHT PLANS	12
7. AUTHORIZATION FOR PERSONNEL TO FLY	8
8. FLIGHT ANNOUNCEMENT (SSO-2)	12
9. FLIGHT INSURANCE APPLICATIONS	24
10. AIRCRAFT PASSENGER MANIFEST (NASA 1269)	12

The remaining SRs were routine requests for specific items, such as reproduction of the Experimenters' Bulletins and repair of specific components (camera shutter, signal leads, etc.).

Purchase request — The eight PRs were typical of any ASO mission, perhaps somewhat fewer than usual. Three pertained to experimenters' grants.

Logistics support correspondence — The arrangements for basing at Cold Bay, Alaska, a civilian airport, were handled by the resident manager of ASO contract services, whereas those for Eielson AFB were handled by the mission manager, since a contractor cannot act as the intermediary between two Government agencies. A work statement to the ASO contract service covered the aircraft service and expedition support needed at Cold Bay. Expedition support was a minimum on this trip, and provided for housing, meals, desk, and telephone for the ASO mission manager, and a room suitable for photographic processing.

Use of the air force facilities in Alaska was arranged through three letters between the Airborne Science Office and the U.S. Air Force. The letters covered the formal request to base at Eielson AFB and to refuel if necessary at Shemya AFB, a request for area clearance (i.e., permission to stay at the base) of the expedition personnel, and communications between the CV-990 airplane and the rocket range at Kiruna, Sweden. All this correspondence was routed through the Air Force Systems Command Liaison Office at Ames to record arrangements already worked out by telephone.

Aircraft flight request — Aircraft flight requests were needed only for the two flights originating at Moffett Field, the practice flight and the ferry flight to Cold Bay. For the flights from the field bases, a tentative schedule was worked out by the mission manager, approved by the command pilot, and amended as needed during the day-to-day operations in the field.

Flight plans — Flight plans, required for each of the 12 flights in accordance with standard operating practice, were made by the flight planner/navigator just a few hours before the flight and after the experimenters' planning meeting. The pilots filed the flight plan by telephone with the FAA Air Traffic Control (ATC) Tower at Cold Bay and with Base Operations at Eielson AFB, both of whom then forwarded the flight plans to the appropriate ATC regional centers.

Authorization for personnel to fly — In late September, the mission manager prepared a master Flight Authorization Letter (FAL), which listed and thereby approved all potential passengers on the expedition's flights. Then before each flight in Alaska, a supplementary FAL was prepared covering passengers originating from the field base; these included passengers from the local FAA Control Tower, the Weather Service, and the Flying Tiger Line, who were supplying direct support to mission flight operations, as well as others connected with experiment teams. These were sent by mail to the Ames Flight Operations Branch.

Flight announcement — Flight announcements are single sheets containing the times of the next flight: boarding, door-closing, take-off, and estimated landing times. They were posted in conspicuous places where the expedition members were likely to gather or pass.

Flight insurance applications — A couple of the regular passengers plus most of the extra, single-flight passengers bought the flight insurance. Since the time of the flight must be entered on the form, the mission manager waited until the flight was certain before he filled in the forms.

Aircraft passenger manifest — These standard forms were prepared by the mission manager a few hours prior to each flight. Then, at boarding time, he or the assistant mission manager checked the manifest against those people actually on board and made any necessary changes in it. The manifest was mailed to Ames with the FAL.

General Comments on the Documentation

Only two of the ten listed categories of documentation originated were peculiar to the ASO—namely, the logistics support correspondence and the flight announcements. The other eight categories of documentation are the same as those developed by Ames and NASA management for use by any Ames group carrying out its research program, particularly a program that requires the use of a NASA airplane.

Appendix E

LEAR JET MISSIONS
(April to November 1972)

The Airborne Science Office (ASO) of the Space Science Division at Ames Research Center operates a Lear Jet program, based at Moffett Field, California, for astronomical, meteorological, and geophysical research experiments. The FY 73 program consisted of nine teams of experimenters performing IR investigations of various astronomical objects.

Each experimenter is normally allotted several one- to two-week flight periods at appropriate intervals during the year. (In the present discussion each of these periods is called a Lear Jet Mission.) Flights of a maximum 3-hour duration are normally flown nightly Monday through Friday. Two flights a night can be accommodated under certain circumstances. Basic aircraft support, integration, flight navigation planning, safety measures, and other services are furnished by Ames support groups operating on a functional basis with the ASO.

Management Procedures

The overall management of the Lear Jet program is the responsibility of the ASO Lear Jet manager, who is the interface between the experimenter and various functional support groups at Ames. These groups include: the Flight Operations Branch (FOB) (pilots and airworthiness engineering), the Aircraft Services Branch (aircraft maintenance), the Inspection Branch, the Metals Fabrication Branch (sheet metal brackets, external fairings, etc.), and the Research Equipment Engineering Branch (mechanical engineering). All are under the management of other directorates at Ames, and thus are not directly responsible to the ASO Lear Jet manager.

The standard Ames aircraft work order is the primary document for alerting and assigning tasks to groups involved with experiment installation (except for the pilots). This one-page document is initiated by the Lear Jet manager and approved by the ASO chief approximately one week before the experimenter arrives at Ames The basic work order is supplemented by a rough sketch of the experiment equipment superimposed on a three-view drawing of the Lear cabin interior, an equipment checklist appropriately marked, and, if the experimenter has previously flown, detailed photographs of the previous installation. The work order provides space for a brief description of the tasks to be performed, the completion date, and the type of airworthiness and safety review required.

The Aircraft Coordinator (Planning Office of the Technical Services Division) first routes the original copy of the work order to the Airworthiness Engineering Group (FOB) for approval of the safety aspects of the overall concept. If questions arise, the Lear Jet manager is called in to provide additional backup information. Copies of the approved work order are then distributed to the appropriate support groups.

The Lear Jet manager next initiates a single-page flight request for a one-week flight series, usually on the Thursday preceding the first flight. It includes flight details, such as dates and times, previously agreed to by the experimenter, the manager, and the ASO flight planners during telephone discussions. The flight request must be approved by the Chief, ASO, and by the Chief, FOB. Pilots are then assigned, and copies of the form are distributed to the Aircraft Services and Inspection Branches. The work order and flight request constitute the entire paperwork effort for the management of the flight series. All other coordination is accomplished in discussions between the support groups and the Lear Jet manager.

On the arrival of a new experimenter, the ASO Lear Jet manager convenes a meeting of all personnel directly involved with the equipment installation. The meeting is informal and normally held in proximity to the experimenter's equipment. The experimenter describes and points out each piece of equipment to the installation crew. From this point on, the support groups work together on a "cut and try" basis to install the equipment, with the ASO manager providing overall coordination.

The flight sequence usually begins on a Tuesday or Wednesday evening. The ASO planner prepares a detailed flight plan and delivers it to the appropriate pilot during the afternoon. The pilot normally contacts the experimenter, and they discuss the experimenter's equipment and objectives. If the experimenter is using the Government-furnished Ames telescope or ancillary equipment, a cognizant Ames experimenter demonstrates its operation and provides a checklist for use during flight. During the flight series, the ASO manager coordinates all activities associated with the experimenter's program.

Experiment Selection

An Announcement of Flight Opportunity (AFO) solicits experiment proposals. The initiative for issuing an AFO often comes from the ASO, sometimes from NASA Headquarters, and rarely from an experimenter. In the normal course of events, AFOs are issued and renewed on a yearly basis. The ASO actually prepares the AFO for issuance by the Public Information Office at Headquarters; distribution is worldwide. The first AFO for Lear Jet flights was issued in 1969.

In response to the AFO, prospective experimenters submit formal proposals for airborne research projects to the sponsoring Headquarters program office, with copies to the Airborne Science Office. The program office, through an *ad hoc* committee of Headquarters and non-NASA scientists, evaluates the scientific merit and the priority of the several proposals. The ASO makes no comment on the scientific merit of a proposal unless requested to do so by Headquarters; the primary concern and input to the committee is how well the proposal fits into the overall airborne research program. An overall guide for the distribution of flight time has been established as follows:

Experiment Origin	Percent of Program Flight Time
NASA	$\leqslant 25$
University	~ 50
Other government agencies	~ 10
Foreign sources	~ 10
Industry	~ 5

To date, there have been no foreign experimenters in the program, partly as a result of funding restrictions and the local availability of similar flight programs. Only U.S. citizens receive full funding (for equipment construction, travel, etc.) with one-year research grants. Foreign scientists are offered funding for aircraft operations; they must finance their own experiment and travel expenses.

Once the accepted research proposals have been announced by Headquarters, the details of the actual funding are completely transferred to the ASO. From this point on, the experimenter deals with the ASO, which has some authority to reallocate funds in emergency situations.

Role of the Experimenter

After his experiment has been selected by NASA Headquarters, and funded through the ASO (with the cooperation of the Ames Office of University Affairs, when appropriate), the experimenter may use the funds in any manner he deems necessary. The only restrictions ASO places on experiment development relate to flight safety and aircraft support limitations (e.g., packaging stress loads, aircraft fastener hardware, weight, power, and aircraft interfaces). The experimenter contacts the ASO Lear Jet manager on an "as required" basis and schedules are tentatively established, based on the experimenter's estimated completion date.

The new experimenter usually visits Ames sometime during the early developmental stages to obtain a first-hand view of the aircraft and typical installation techniques. He meets the various support personnel who will eventually assist in his installation and, at that time, he is encouraged to deal directly with them when questions or problems arise in their area of specialization. The experimenter is provided a Lear Jet Experimenters' Handbook, which explains the aircraft interface requirements and the experiment documentation that he must supply, such as equipment drawings, a stress analysis, and a proposed aircraft layout. In practice, the average new experimenter working in a university laboratory requires some assistance from ASO to complete these items prior to his arrival at Ames.

Experimenters are required to complete a high-altitude indoctrination course at an appropriate military installation. ASO handles the approval and scheduling arrangements, but the experimenter is responsible for his own travel to the base.

Once the flight series starts, the ASO manager continues as overall coordinator but has relatively little direct input to the operations. The experimenter is responsible for maintaining his equipment and verifying that it is flight ready: preflight "count downs," experiment checkouts, etc., are at his discretion. The experimenter is free to remove, dismantle, and repair any equipment during the flight series. Based on the data and/or equipment problems, the experimenter may decide to deviate from the preplanned mission and change the target objectives, subject only to the availability of pilots for the new flight schedule.

At the conclusion of the flight series the experimenter assists in the removal of his equipment and is solely responsible for its packaging. After packing his gear, the experimenter has no further obligations to the ASO. Reports, other than those specified by the grant-funding agreement, are not required. (See Documentation.)

In the April to November 1972 period there were 17 flight series (missions). Two were flown by new experimenter teams entering the Lear Jet program; the remaining 15 missions involved scientists with prior ASO flight experience, using experiments little changed from the previous outing.

Interaction between Experimenter and Management

The ASO makes few demands of the experimenter; the major emphasis is placed on meeting his requirements. A "low profile" is maintained, and other than requiring that the experimenter comply with flight safety regulations and aircraft constraints, the ASO encourages him to operate as he would in his own laboratory. Prior to the experimenter's arrival at Ames, telephone conversations are the primary means of interaction between the ASO manager and the experimenter. To a lesser extent, the experimenter and other Ames support personnel maintain telephone contact, with either party initiating the call.

It has been found that the most difficult problem for the experimenter is the consideration of aircraft factors (safety considerations, acceleration loading, use of aircraft-approved hardware, etc.). On request, the ASO will furnish aircraft-approved hardware and standard Lear Jet experiment racks for mounting equipment. If the experiment seems more complex than usual, a cognizant design engineer may be sent to the experimenter's laboratory to advise him on equipment and installation design. As construction activities near completion, the experimenter is requested to establish a flight period and target objectives. This is fitted to the overall Lear Jet schedule with some give-and-take to accommodate all concerned. In practice, few "first time" experimenters meet the schedule as first worked out.

Approximately two weeks before the experimenter is scheduled to arrive at Ames, he is contacted to reconfirm any special requirements he might have (special mounting brackets, cryogenics, vacuum equipment, a gyro-stabilized mirror, etc.), and to arrange the final flight schedule. He is also requested to furnish the individual and total weight of the experiment packages and their power consumption (total power and amount of 400 Hz, 60 Hz, and 28 Vdc required). At this time, arrangements also are made for the experimenter and his assistant(s) to attend the mandatory high altitude indoctrination course at the beginning of their first week at Ames.

On the experimenter's first flight series, the Lear Jet is normally scheduled for a 2-week period. The experiment team usually arrives at Ames on Monday morning and immediately begins unpacking the experiment. An informal meeting is held, and the experimenter describes his equipment to all personnel who will be involved with the installation and flight series. Later, the necessary measurements are made, and instructions issued to the service groups to fit the experiment into the aircraft.

As the installation proceeds, the airworthiness engineering and aircraft inspection delegates review the progress, and are authorized to hold up the installation if deviations from acceptable practice are noted. If discrepancies occur, they are corrected and installation resumes. The experiment is first "trial assembled" in the aircraft, but not bolted down until the airworthiness engineer gives approval. The completed installation is again reviewed by the aircraft inspector and the airworthiness engineer, and by the command pilot. Installation generally requires 2 to 3 days.

The ASO recommends that the first flight be a checkout and familiarization exercise during daylight hours. This procedure often is resisted by the experimenter, who usually wants to begin his research on the first flight. The flight series usually consists of two to three flights the first week and four the second, with pilots furnished from a group of nine who fly the Lear Jet.

Experimental Equipment

Design and Construction

Most of the experimental equipment (e.g., Dewars, spectrometers, photometers) and the data-recording devices have been built and used in ground-based operations prior to their use in the Lear Jet program. Thus, the major design and fabrication effort usually is the preparation of mounting brackets to attach the detector assembly to the Government-furnished, 30-cm open-port telescope, and the fabrication of appropriate housings for electronic equipment. (The original 30-cm, open-port telescope was largely an in-laboratory design and fabrication effort over a period of several years by members and associates of Lear Jet Group 5. The Lear GFE telescope is essentially a replica of this original, made in the Ames laboratories and shops.) Experimenters not using the GFE telescope may design short focal length, small-aperture telescopes or housings with reflecting mirrors to fit within the limited dimensions of the Lear Jet cabin.

The Lear Jet experimenter's equipment normally consists of a mixture of off-the-shelf and custom equipment. Table E-1 gives characteristics of experiments in the April to November 1972 period. The Dewar assembly for the cryogenic cooling of an IR detector is often a custom-commercial product. The detector assembly, housed within the Dewar may be a custom-commercial unit, may be made in the experimenter's laboratory, or a mixture of both. The first stages of the signal-processing equipment, including detector bias supplies, preamplifiers, and any special electronics for the angular or linear movement of gratings, mirrors, etc., are usually experimenter designed and fabricated. The later stages of signal amplification and processing are normally handled by off-the-shelf equipment. This gear typically will consist of amplifiers,

TABLE E-1. EXPERIMENT CHARACTERISTICS

(LEAR JET EXPERIMENTS, APRIL TO NOVEMBER, 1972)

EXPERIMENT (NUMBER OF MISSIONS)	COMPONENT	CONSTRUCTION TYPE/SOURCE			
		OFF-THE-SHELF	CUSTOM-COMMERCIAL	MODIFIED-COMMERICAL	EXPERIMENTER BUILT
1. VISIBLE WAVELENGTH ASTRONOMY; SPECTROSCOPY OF NEBULAE (2)	HELIOSTAT (GFE)				
	HELIOSTAT STABILIZATION SYSTEM (GFE)				
	ECHELLE SPECTROGRAPH		X		
	BENT CASSEGRAIN TELESCOPE		X		
2. METEORIC DUST CONCENTRATION (3)	COUNTER	X			
	PULSE HEIGHT ANALYZER				X
	OSCILLOSCOPE	X			
	LASER	X			
	PHOTOMULTIPLIER TUBES (2 PLUS 2 SPARES)	X			
	PMT OPTICS				X
	PMT POWER SUPPLIES	X			
	PMT PREAMPLIFIERS				X
3. FAR IR ASTRONOMY; SPECTRA OF THE GALACTIC CENTER, NEBULAE, ISOTROPIC RADIATION (3)	30-cm TELESCOPE SYSTEM (GFE)				
	TELESCOPE STABILIZATION SYSTEM (GFE)				
	VACUUM PUMP (GFE)				
	DEWAR/DETECTOR	X			
	FABRY-PEROT INTERFEROMETER	X			
	FABRY-PEROT DRIVE	X			
	STRIP CHART RECORDER	X			
	TIMER/COUNTER	X			
	LOCK-IN AMPLIFIER	X			
	TAPE RECORDER	X			
	COMPUTER OF AVERAGE TRANSIENTS	X			
4. FAR IR ASTRONOMY; SPECTRA OF THE GALACTIC CENTER, NEBULAE, PLANETS (5)	30-cm TELESCOPE				X
	TELESCOPE STABILIZATION SYSTEM				X
	HELIUM DEWAR AND DETECTOR		X		
	PHASE LOCK AMPLIFIER	X			
	TAPE RECORDER	X			
	STRIP CHART RECORDER	X			
	OSCILLOSCOPE	X			
	MICHELSON INTERFEROMETER	X			
	COMPUTER TO DRIVE INTERFEROMETER AND RECORD DATA			X	
	VACUUM PUMP (GFE)				

TABLE E-1. EXPERIMENT CHARACTERISTICS (CONCLUDED)
(LEAR JET EXPERIMENTS, APRIL TO NOVEMBER, 1972)

EXPERIMENT (NUMBER OF MISSIONS)	COMPONENT	CONSTRUCTION TYPE/SOURCE			
		OFF-THE-SHELF	CUSTOM-COMMERCIAL	MODIFIED-COMMERCIAL	EXPERIMENTER-BUILT
5. FAR IR ASTRONOMY; RADIOMETRY OF THE GALACTIC CENTER, NEBULAE, STARS, PLANETS (1)	30-cm TELESCOPE SYSTEM				X
	TELESCOPE STABILIZATION SYSTEM				X
	HELIUM DEWAR AND DETECTOR		X		
	LOW NOISE PREAMPLIFIER	X			
	SIGNAL CHANNEL ELECTRONICS				X
	CHOPPER DRIVER AND PHASE REFERENCE				X
	INVERTER	X			
	MAGNETIC TAPE RECORDER	X			
	STRIP CHART RECORDER	X			
	MULTICHANNEL DIGITAL PRINTER	X			
	VACUUM PUMP	X			
	OSCILLOSCOPE	X			
6. NEAR IR ASTRONOMY; INTERFEROMETRY OF PLANETS AND STARS (1)	AMPLIFIER		X		
	SIGNAL MIXER				X
	HELIOSTAT (GFE)				
	HELIOSTAT STABILIZATION SYSTEM (GFE)				
	30-cm TELESCOPE AND STABILIZATION SYSTEM (GFE)				
	INTERFEROMETER	X			
	INTERFEROMETER DRIVE	X			
	MOUNTING PLATFORM				X
	DEWAR (2)				X
	TAPE RECORDER	X			
	OPTICAL WINDOW		X		
	VACUUM PUMP	X			
	OSCILLOSCOPE	X			
7. & 8. FAR IR ASTRONOMY; SPECTRA OF THE GALACTIC CENTER, NEBULAE, PLANETS (1 EACH)	30-cm TELESCOPE SYSTEM (GFE)				
	TELESCOPE STABILIZATION SYSTEM (GFE)				
	DETECTOR DEWARS (2) 7. CASSEGRAIN OPTICS, Cu/Ge DETECTOR (1), 16-23 μm 8. FOLDED OPTICS, TWO DETECTORS; Cu/Ge DETECTOR, 16-28 μm; Zn/Ge DETECTOR, 20-40 μm				X
	LOCK-IN AMPLIFIER	X			
	GRATING				X
	TAPE RECORDER	X			
	OSCILLOSCOPE	X			
	SCAN-STEP CONTROL				X
	VOLTAGE TO FREQUENCY CONVERTER				X
	AUDIO AMPLIFIER				X

voltage-controlled oscillators, and tape recorders. In recent months, some experimenters have introduced small data-processing units into their systems to provide either real-time (experiments 3 and 4, table E-1) or postflight (8) data processing.

The experimenter, with ASO assistance, resolves any specific problems of adapting the existing experiment to the Lear Jet environment. The vibration modes, the acceleration loading, the safety considerations, and the aircraft-approved hardware are design restraints not encountered in laboratory research. The experimenter frequently will underestimate the influence of aircraft vibrational modes on the performance of his equipment, and since the ASO does not require a preflight vibration acceptance test, any problems of this nature arise during the first flight series. Another problem is the overdesign of major equipment housings; the resultant weight penalty lowers the aircraft ceiling altitude. Although both these potential problem areas are explained to the experimenter, a completely satisfactory solution may not be achieved for the first flight series. Equipment constructed for normal ground-base use can usually be adapted to aircraft operation with relatively minor modifications if the design restraints are carefully followed.

Checkout

The experimenter has total responsibility for the checkout and operational verification of his equipment prior to arrival at Ames. The ASO does not witness the laboratory testing or require a written test report from the experimenter. On arrival at Ames, the experimenter is responsible for unpacking his equipment, assisting in the installation, and performing any operational checks he deems necessary. The ASO does not require an operational or integration test prior to flight time and the proper operation of the equipment is totally the responsibility of the experimenter.

In normal practice, the experimenter spends the first day assisting in the installation and the second day, until flight time, checking and aligning his equipment. Two areas of the equipment installation are checked by Ames: total power consumption and mechanical installation. Before each piece of electronic equipment is added to the 60-Hz or 400-Hz load, a current measurement is made using a ground power source. Equipment is added to the inverter load up to approximately three-fourths of full capacity. Additional inverters are installed on the aircraft as needed.

A mechanical analysis of the installation is performed by both an aircraft inspector and an airworthiness engineer, to ensure the installation is safe and airworthy. Problems arising during the flight series are, again, the responsibility of the experimenter; all repairs and checkouts are performed by him. Support assistance can be furnished by ASO if requested to meet the flight schedule.

Interface Requirements

The Lear Jet Experimenters' Handbook specifies the aircraft interface requirements for the experiment and contains detailed drawings and pertinent dimensions of the cabin, baggage area, and viewport locations. Due to the Lear Jet's relatively small size, the major interface constraint usually turns out to be volume.

The ASO provides a 30-cm IR telescope mounted in a special viewport, racks and pallets for mounting ancillary equipment, a gyro-stabilized mirror, and inverters to furnish equipment power. For most experiments, the interface is with the GFE telescope rather than the aircraft proper. Information on the telescope adapter ring, racks and pallets, and the gyro-stabilized mirror is given in the Experimenters' Handbook. The main task of the experimenter prior to arriving at Ames is to fabricate interface supports for the telescope adapter ring, and make a rough layout of the floor plan.

The weight restriction on an experiment is typically 600 to 700 pounds. Most experiment components have been designed for ground-based operation where weight is usually not a limitation. In practice, the experimenter does not attempt to lighten the structures of a given unit, since, except for its effect on aircraft ceiling altitude, weight is not of critical importance.

A few experimenters have proposed larger experiments requiring direct interface with the aircraft structure. In this case the experimenter, or his contractor, travels to Ames to make detailed measurements for an outline drawing of the installation, from which Ames shops fabricate a mockup. Under the direction of the ASO manager, this mock-up is then fitted in the aircraft to ensure that the installation will meet all interface criteria.

The ASO does not require the experimenter to submit detailed interface drawings showing the installation and layout of all equipment in racks. Upon arrival at ARC, the final interface matching is performed on a "trial basis"; that is, the equipment is installed in the racks and loosely tied down. Equipment to be installed in the baggage compartment is positioned for optimum layout by the experimenter and the ground crew. The mechanical engineer and sheet-metal technician are then called in, and any special brackets, plates, etc., required to pick up existing hole patterns are designed on the spot. The airworthiness engineer and aircraft inspector review the final installation; if it is approved, they sign off the aircraft work order originally initiated by the ASO Lear Jet manager. This approves the aircraft for flight.

Experiment Reliability

The ASO Lear Jet program does not require a formal reliability or quality assurance program. The experimenter can use any commercial or custom equipment normally acceptable in a standard laboratory. Parts and subassemblies can be procured from vendors available to the experimenter; parts may be used in any manner deemed acceptable, and no derating guidelines are recommended. The fabrication and construction techniques used to assemble components internal to the custom equipment, are at the discretion of the experimenter. During the experimenter's flight series, he has complete freedom to remove experimental equipment from the aircraft, dismantle, troubleshoot, and repair on the spot. Ames personnel do not monitor or inspect parts replacement, construction, or installation techniques used within the housings of experimental units. Some of the more severe problems encountered in flight are listed in table E-2; in all these cases, repairs were made on the ground rather than in flight. With few exceptions, the experimenter had the required spare parts on hand.

TABLE E-2. EXPERIMENT PROBLEMS IN FLIGHT
(LEAR JET MISSIONS, APRIL TO NOVEMBER, 1972)

EXPERIMENT	PROBLEM DESCRIPTION	IMPACT ON DATA		
		NONE	LIMITED	SEVERE
1. VISIBLE WAVELENGTH ASTRONOMY	TRANSISTOR OUT IN STABILIZED MIRROR AMPLIFIER			X
2. METEORIC DUST CONCENTRATION	PULSE-HEIGHT ELECTRONICS FAILED		X	
	PHOTOMULTIPLIER FAILED			X
	MONITOR OSCILLOSCOPE FAILED			X
	OPTICS ICED OVER			X
	A/C ELECTRICAL NOISE PICKUP		X	
	AMPLIFIER OSCILLATING		X	
3. FAR IR ASTRONOMY	ARCING PIEZOELECTRIC CRYSTALS IN INTERFEROMETER OPTICS DRIVE			X
	LOCK-IN AMPLIFIER FAILED			X
4. FAR IR ASTRONOMY	IR DETECTOR FAILED			X
	MONITOR SCOPE FUSE BLEW OUT	X		
	ROLL STABILIZING GYRO ON TELESCOPE FAILED			X
	CRYOGENIC LEAK IN DETECTOR DEWAR			X
	WEAK YAW CONTROL ON TELESCOPE			X
5. FAR IR ASTRONOMY	BATTERY FAILED IN TELESCOPE CONTROL SYSTEM		X	
	POOR TELESCOPE STABILIZATION			X
6. NEAR IR ASTRONOMY	TAPE RECORDER FAILED		X	
	A/C ELECTRICAL NOISE PICK-UP		X	
7. FAR IR ASTRONOMY	SPECTROMETER GRATING MOTION JAMMED			X
	YAW-AXIS CONTROL ON TELESCOPE FAILED			X
8. FAR IR ASTRONOMY	AMPLIFIER SATURATED		X	

Safety

One of the prime considerations of the Lear Jet program is the safety of the crew and the experimenters. The Experimenters' Handbook for the Lear Jet specifies the use of NASA hardware and fasteners for all equipment housings, and the performance of a stress analysis to verify that the overall housing and support framework can withstand the aircraft flight and crash loads as specified by the FAA. The mounting of the experimenter's equipment on the standard GFE racks is supervised and inspected by the Ames airworthiness and design engineers. Heavier or larger equipment that is mounted in the baggage compartment is handled by Ames engineers. The final design and assembly is inspected by the design engineer, the airworthiness engineer, the aircraft inspector, and the command pilot. The airworthiness and inspection personnel sign the aircraft work order certifying the installation is airworthy.

The Ames FOB maintains an airworthiness engineering group that reviews the original work order, installation drawings, and stress analyses to ensure that each basic experimental concept meets aircraft safety requirements. The work order must be signed by the airworthiness engineer before any installation or fabrication of equipment on the aircraft can proceed.

If the installation appears to be complex or controversial, the airworthiness engineering group may elect to request a special review by the Airworthiness and Flight Safety Review Board, which consists of appointed specialists from various facilities at Ames. The Board has been convened for a number of experiments in the Lear Jet program, and their decision is considered final.

A second safety requirement is that the installed equipment allows room for safe and rapid egress and ingress from the cabin. Equipment is "trial positioned" prior to final tie-down to ensure the minimum allowable clearances are maintained for all pathways leading to the emergency exit.

After the experiment has been installed, all people flying on the aircraft must have an ear, nose, and throat examination at the Ames health unit to ensure against complications resulting from high-altitude flight.

Documentation

During the grant performance period, the experimenter is required to make verbal progress reports to the ASO Lear Jet manager on a monthly basis. Brief semiannual and annual reports are submitted in writing. The experimenter is also required to submit a written Quarterly Cash Requirement Report to establish funding needs.

Experimenters operating under a grant are requested to submit technical preprints to NASA prior to publication in a scientific journal; reprints of the article must be submitted soon after publication. The publications do not require approval unless a security classification is involved. On completion of the research, the experimenter must submit a final technical report to NASA that summarizes the results of the entire project.